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UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

Fishery Resources

FISHERY AND AQUATIC MANAGEMENT PROGRAM
in
YELLOWSTONE NATIONAL PARK

Technical Report for Calendar Year 1986

June 1987

FEDERAL

ANNUAL PROJECT TECHNICAL REPORT FOR 1986

Fishery and Aquatic Management Program

Yellowstone National Park

Ronald D. Jones, Project Leader

June 1987

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Cover photo: Setting nets off Cub Creek, 1900-1920.

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INTRODUCTION

Yellowstone National Park is located in the northwest corner of Wyoming and small adjacent areas of the states of Montana and Idaho. It occupies an area of almost 915,000 ha (3,500 sq. mi) astride the continental divide and is bordered by mountains on the north and east sides which rise to 3,400 m (11,000 ft). The park is characterized by several broad, forested volcanic plateaus, containing the world's largest caldera and thousands of thermal features.

Slightly over five percent of the landmass of Yellowstone Park is covered with water. Specifically, over 150 lakes comprise an area of approximately 43,000 ha (107,000 acres). Yellowstone Lake, Shoshone Lake, Lewis Lake, and Heart Lake make up 94% of the total lake area. Elevations of park lakes range from 1,700 to 3,000 m (5,500 to 9,700 ft) above sea level. Additionally, over 220 named and hundreds of unnamed streams make up over 4,300 km (2,650 mi) or approximately 2,000 ha (5,000 acres) of running water.

In 1872, the United States Congress established Yellowstone National Park "... for the benefit and enjoyment of the people and for the preservation, from injury and spoilation of all timber, mineral deposits, natural curiosities or wonders..., and their retention in their natural condition". From this beginning, federal legislation and policies have evolved to prohibit hunting of all birds and mammals and to regulate fishing. The park is currently managed for the perpetuation of natural processes within the Yellowstone ecosystem, including interactions between and among native fauna, flora, geology, and scenic landscapes (Houston 1971).

Yellowstone Park represents one of the few remaining pristine aquatic ecosystems in the contiguous United States. These natural systems contain, sustain, and protect many diverse varieties of aquatic organisms.

Angling has always been a major visitor activity in Yellowstone Park. Although initial regulations were extremely liberal and associated with frontier subsistence, present restrictions have developed over the past 50 years to more closely reflect the park's management mandate. Basic objectives of the aquatic management program are to:

1. Manage aquatic systems as an integral part of the park ecosystem.
2. Preserve and restore native species and aquatic habitats.

3. Provide recreational fishing opportunities for enjoyment of park visitors consistent with the first two objectives.

Attainment of these objectives requires that angler impacts do not alter natural replenishment rates, size and age structure, or significantly reduce numbers, from those occurring in unfished populations. This management policy provides the angler with the opportunity to fish for wild trout in a natural setting. It also requires that anglers distinguish between catching fish as a recreational experience and removing fish for consumption.

Protective policies of the National Park Service that have prevented significant degradation of the aquatic habitat have also restricted the use of stocking to native species restoration projects. Special regulations have become the primary means to accomplish park fishery objectives. Regulations used to protect the fishery have included manipulating season dates, bait and terminal gear restrictions, and the use of size and creel limits (including catch and release). Additionally, some waters have been closed to angling in order to protect threatened species, nesting birds, or provide scenic vistas with undisturbed wildlife and fish.

Yellowstone Park has one fish species (Montana grayling) and over a dozen waters restricted to catch and release fishing. Several other waters, including Yellowstone Lake, require the release of some fish as a result of maximum or minimum size limits. The implementation of these regulations has improved the angling experience despite substantial angler use, and population structure more closely resembles historic levels.

In 1986, approximately 163,300 non-fee permits were issued to potential park anglers. Permitees came from all 50 states, all Canadian provinces, and several other foreign countries (Table 1). The largest single group resided in local states of Montana, Wyoming, Idaho, and Utah.

The 1980 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (USFWS 1982) indicated that Yellowstone Park annually supports approximately 1.3% of the nation's trout anglers. Of 120 lakes and streams which are utilized by park anglers, 30 support most of the fishing pressure. The quality of at least six of these fisheries has gained national recognition, and several articles, usually complimentary, are published about Yellowstone fishing each year.

Table 1. Residency of anglers[1] interviewed when leaving Yellowstone National Park, 1976 and 1978-86.

States by geographical groups	Number interviewed at entrance stations										Percentage of total interviewed									
	1976	1978	1979	1980	1981	1982	1983	1984	1985	1986	1976	1978	1979	1980	1981	1982	1983	1984	1985	1986
"Local states"																				
Idaho	37	47	61	23	71	55	86	52	50	23	2.79	3.91	4.96	3.38	4.64	4.42	5.09	3.64	4.69	3.04
Montana	68	46	62	49	79	79	78	70	57	34	5.14	3.83	5.04	7.20	5.17	6.35	4.62	4.90	5.35	4.49
Utah	71	97	112	50	141	103	128	131	107	70	5.36	8.07	9.10	7.34	9.23	8.28	7.58	9.17	10.04	9.25
Wyoming	67	58	58	23	89	62	100	63	63	45	5.06	4.82	4.71	3.38	5.82	4.98	5.92	4.41	5.91	5.94
Total	243	248	293	145	380	299	392	316	277	172	18.35	25.48	23.80	21.29	24.87	24.04	23.22	22.11	25.98	22.72
West coast states																				
California	225	158	222	102	228	198	270	225	165	101	16.99	13.15	18.03	14.98	14.92	15.92	16.00	15.75	15.48	13.34
Oregon	24	34	24	23	40	36	56	50	24	21	1.81	2.83	1.95	3.38	2.62	2.89	3.32	3.50	2.25	2.77
Washington	56	49	48	21	54	64	69	73	34	27	4.23	4.07	3.90	3.08	3.53	5.14	4.09	5.11	3.19	3.57
Total	305	241	294	146	322	298	395	348	223	149	23.03	20.05	23.88	21.44	21.07	23.95	23.40	24.35	20.92	19.68
Southwest states																				
Arizona	18	28	26	22	41	23	42	28	20	15	1.36	2.33	2.11	3.23	2.68	1.85	2.49	1.96	1.88	1.98
Colorado	65	65	80	47	118	111	163	130	89	57	4.91	5.41	6.50	6.90	7.72	8.92	9.66	9.10	8.35	7.53
Nevada	7	4	10	4	12	7	14	15	11	11	0.53	0.33	0.81	0.59	0.79	0.56	0.83	1.05	1.03	1.45
New Mexico	9	8	9	6	16	18	15	21	10	9	0.68	0.67	0.73	0.88	1.05	1.45	0.89	1.47	0.94	1.19
Total	99	105	125	79	187	159	234	194	130	92	7.48	8.74	10.15	11.60	12.23	12.78	13.86	13.58	12.20	12.15
Central plains states																				
Iowa	15	25	17	13	28	21	33	21	14	17	1.13	2.08	1.38	1.90	1.83	1.69	1.95	1.47	1.31	2.25
Kansas	14	12	8	7	26	14	21	21	17	11	1.06	1.00	0.65	1.03	1.70	1.13	1.24	1.47	1.59	1.45
Nebraska	18	15	21	10	22	19	19	10	17	7	1.36	1.24	1.71	1.47	1.44	1.53	1.13	0.70	1.59	0.92
North Dakota	10	12	2	8	10	8	20	7	5	10	0.76	1.00	0.16	1.17	0.65	0.64	1.18	0.49	0.47	1.32
Oklahoma	14	7	10	11	28	18	20	23	13	9	1.06	0.58	0.81	1.62	1.83	1.45	1.18	1.61	1.22	1.19
South Dakota	9	14	8	5	5	11	12	4	11	4	0.68	1.16	0.65	0.73	0.32	0.88	0.71	0.28	1.03	0.53
Texas	42	52	43	30	57	46	68	59	64	29	3.17	4.32	3.49	4.41	3.73	3.70	4.03	4.13	6.00	3.83
Total	122	137	109	84	176	137	193	145	141	87	9.22	11.38	8.89	12.33	11.52	11.01	11.43	10.15	13.23	11.49
North central states																				
Illinois	70	48	40	26	56	32	47	53	25	19	5.29	4.00	3.25	3.82	3.66	2.57	2.78	3.71	2.35	2.51
Indiana	20	23	11	3	10	7	15	20	12	5	1.51	1.91	0.89	0.44	0.65	0.56	0.89	1.40	1.13	0.66
Michigan	58	61	47	13	42	27	39	33	25	12	4.38	5.07	3.82	1.91	2.75	2.17	2.31	2.31	2.35	1.59
Minnesota	64	44	31	17	44	39	63	32	29	28	4.83	3.66	2.52	2.50	2.88	3.14	3.73	2.24	2.72	3.70
Ohio	49	40	22	19	32	32	33	32	21	14	3.70	3.33	1.79	2.79	2.09	2.57	1.95	2.24	1.97	1.85
Wisconsin	40	37	31	23	44	25	35	35	26	32	3.02	3.08	2.52	3.38	2.88	2.00	2.07	2.45	2.44	4.23
Total	301	253	182	101	228	162	232	205	138	110	22.73	21.05	14.78	14.83	14.92	13.02	13.74	14.35	12.95	12.53
Southern states																				
Alabama	3	3	1	2	2	6	3	4	2	5	0.23	0.24	0.08	0.29	0.13	0.48	0.18	0.28	0.19	0.66
Arkansas	1	4	6	3	5	4	5	7	6	6	0.08	0.33	0.49	0.44	0.33	0.32	0.30	0.49	0.56	0.79
Florida	22	14	20	12	23	13	42	32	20	23	1.66	1.16	1.62	1.76	1.50	1.05	2.49	2.24	1.88	3.04
Georgia	7	10	7	5	7	7	10	9	5	5	0.53	0.83	0.57	0.73	0.46	0.56	0.59	0.63	0.47	0.66
Kentucky	7	2	4	3	7	4	6	4	4	5	0.53	0.16	0.32	0.44	0.46	0.32	0.36	0.28	0.38	0.66
Louisiana	5	4	5	1	6	4	4	5	4	3	0.38	0.33	0.41	0.15	0.39	0.32	0.24	0.35	0.38	0.40
Mississippi	5	8	3	3	5	7	5	3	7	3	0.38	0.66	0.24	0.44	0.33	0.56	0.30	0.21	0.66	0.40
Missouri	19	19	23	12	11	13	24	26	23	16	1.44	1.58	1.87	1.76	0.72	1.05	1.42	1.82	2.16	2.11
North Carolina	9	9	6	2	3	9	3	3	4	5	0.68	0.79	0.49	0.29	0.20	0.72	0.18	0.21	0.38	0.66
South Carolina	5	4	3	1	3	2	2	2	1	0	0.38	0.33	0.24	0.15	0.20	0.16	0.12	0.14	0.09	0.00
Tennessee	7	1	4	0	4	7	11	4	3	8	0.53	0.08	0.32	0.00	0.26	0.32	0.65	0.28	0.28	1.06
Virginia	11	4	7	6	10	9	12	10	8	6	0.83	0.33	0.57	0.88	0.65	0.72	0.71	0.70	0.75	0.79
Washington, D.C.	1	0	0	0	0	0	0	0	0	0	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West Virginia	4	4	1	2	3	3	1	4	1	3	0.30	0.33	0.08	0.29	0.20	0.24	0.06	0.28	0.09	0.40
Total	106	86	90	52	89	85	128	113	88	88	8.03	7.15	7.31	7.64	5.82	6.83	7.58	7.91	8.26	11.62
Northeast states																				
Connecticut	10	11	13	7	3	7	8	10	2	1	0.76	0.95	1.06	1.03	0.20	0.56	0.47	0.70	0.19	0.13
Delaware	1	0	0	1	1	3	0	0	1	1	0.08	0.00	0.00	0.15	0.07	0.24	0.00	0.00	0.09	0.13
Maine	2	1	0	1	4	2	1	1	3	2	0.15	0.08	0.00	0.15	0.26	0.16	0.06	0.07	0.28	0.26
Maryland	14	9	9	7	8	7	4	5	2	7	1.06	0.74	0.73	1.03	0.52	0.56	0.24	0.35	0.19	0.92
Massachusetts	10	6	9	7	8	4	6	9	5	2	0.76	0.49	0.73	1.03	0.52	0.32	0.36	0.63	0.47	0.26
New Hampshire	3	2	2	2	2	2	0	2	1	3	0.23	0.16	0.16	0.29	0.13	0.16	0.00	0.14	0.09	0.40
New Jersey	14	12	17	10	17	12	18	12	14	5	1.06	1.00	1.38	1.47	1.11	0.96	1.07	0.84	1.31	0.66
New York	28	27	31	12	27	11	17	15	14	15	2.11	2.24	2.51	1.76	1.77	0.88	1.01	1.05	1.31	1.98
Pennsylvania	26	41	25	10	34	29	33	29	20	16	1.96	3.41	2.03	1.47	2.23	2.33	1.95	2.03	1.88	2.11
Rhode Island	1	0	1	0	3	1	1	0	0	1	0.08	0.00	0.08	0.00	0.20	0.08	0.06	0.00	0.00	0.13
Vermont	1	1	3	0	1	2	2	3	2	0	0.08	0.08	0.24	0.00	0.07	0.16	0.12	0.21	0.19	0.00
Total	110	110	110	57	108	80	91	86	64	53	8.33	9.15	8.94	8.37	7.07	6.43	5.39	6.02	6.00	7.00
Isolated states																				
Alaska	3	1	1	1	2	1	0	2	0	2	0.23	0.08	0.08	0.15	0.13	0.08	0.00	0.14	0.00	0.26
Hawaii	2	1	1	2	0	2	0	2	1	0	0.15	0.08	0.08	0.29	0.00	0.16	0.00	0.14	0.09	0.00
Total	5	2	2	3	2	3	0	4	1	2	0.38	0.16	0.16	0.44	0.13	0.24	0.00	0.28	0.09	0.26
Canada	33	19	12	11	31	16	22	17	3	2	2.49	1.58	0.97	1.62	2.03	1.28	1.30	1.19	0.28	0.26
Foreign countries	0	0	14	3	5	5	1	1	1	2	0.00	0.00	1.14	0.44	0.33	0.40	0.06	0.07	0.09	0.26
GRAND TOTAL w/o Canada	1291	1182	1205	667	1492	1223	1685	1411	1062	753										
GRAND TOTAL w/ Canada	1324	1201	1217	678	1523	1239	1687	1428	1065	755										
GRAND TOTAL w/ Canada and foreign countries	1324	1201	1231	681	1528	1244	1688	1429	1066	757										

[1] Persons who obtained fishing permits.

In order to manage the diverse and complex aquatic resources of Yellowstone National Park, this project conducts annual investigations which provide information necessary to evaluate the fishery management program and monitor its adherence to park objectives. The following report details results of our efforts during 1986.

PARKWIDE ANGLING

Although park recreational visitation (2.2 million visitors) increased (6.2% more than 1985) in 1986, issuance of non-fee fishing permits decreased 2.0% (Table 2). Approximately 163,300 permits were issued; however, gate survey data indicated that 26.5% of the permit holders did not fish. After adjustments were made for nonanglers, the number of park anglers was estimated at 124,900. This represents a 0.9% increase in the number of anglers since 1985.

The exit gate survey indicated that anglers spent an average of 1.83 days fishing in the park and fished approximately 1.29 different waters/day. Estimates of total use (294,800 angler days) and effort (734,700 angler hours) were calculated using the method of Jones et al. (1977). Both figures are among the lowest estimates since 1976 (Table 2).

The Volunteer Angler Report (VAR) system estimated that 740,900 fish were landed and 73,436 creeled at a rate of 1.01 and 0.10 fish/hour, respectively (Table 3). Of the fish landed, 92% were released and 8% creeled. The number of fish landed per average angler trip (2.49 hours) was 2.51, and the number creeled was 0.25 (Table 4).

Species composition was indicated by anglers for 41,783 landed fish; 76.2% were reported to be cutthroat trout, followed by rainbow trout (8.5%), brown trout (6.1%), brook trout (5.1%), and lake trout (2.2%). Small numbers of grayling, mountain whitefish, and unidentified fish were also caught.

Average size of landed fish (338 mm or 13.3 in) remained unchanged from 1985. Of 39,365 fish, about 70% were greater than 305 mm (12 in), and 52% exceeded 356 mm (14 in). Average length of creeled fish was 313 mm (12.3 in). Lake trout were the largest fish landed (419 mm or 16.5 in) followed by cutthroat trout (359 mm or 14.1 in), whitefish (312 mm or 12.3 in), brown trout (290 mm or 11.4 in), unknown species (280 mm or 11.0 in), rainbow trout (273 mm or 10.8 in), grayling (196 mm or 7.7 in), and brook trout (195 mm or 7.7 in).

Prior to 1985, positive bias in mean length was suspected in VAR parkwide estimates because 229 mm (9 in) represented the minimum size which could be reported. In order to improve the sensitivity and accuracy of the VAR system, three new length categories were initiated in 1985; minimum size was reduced to

Table 2. Estimates of park recreational visitation, fishing permits issued, total parkwide anglers, and total parkwide angler days, Yellowstone National Park, 1972-86.

Year	Total Park Recreational Visitation	Park Fishing Permits Issued	Total Parkwide Anglers	Total Parkwide Angler Days	95% Confidence Limits
1972	2,246,827	-----	-----	-----	-----
	--	--	--	--	--
1973	2,061,537	169,103	121,888	230,100	225,500-
	-8.2%[1]	--	--	--	234,700
1974	1,928,915	164,600	116,518	220,000	215,500-
	-6.4%	-2.7%	-4.4%	-4.4%	224,300
1975	2,239,483	191,550	136,322	257,300	248,400-
	+13.9%	+16.4%	+17.0%	+17.0%	266,300
1976	2,519,224	213,200	151,730	284,200	278,500-
	+12.5%	+11.3%	+9.7%	+10.5%	289,900
1977	2,481,933	217,000	154,581	311,300	304,000-
	-1.5%	+1.8%	+1.9%	+9.5%	318,500
1978	2,618,380	218,000	155,700	333,800	326,200-
	+5.5%	+0.5%	+0.7%	+7.2%	341,300
1979	1,892,908	195,100	139,100	291,300	274,500-
	-27.7%	-10.5%	-10.7%	-12.7%	308,200
1980	2,000,273	184,200[2]	130,800	311,300	287,000
	+5.7%	-5.6%	-6.0%	+6.9%	334,600
1981	2,521,831	172,300	160,000	383,400	363,400-
	+26.1%	-6.5%	+22.3%	+23.2%	403,300
1982	2,368,897	205,000	152,000	332,500	314,700-
	-5.9%	+19.0%	-5.0%	-13.3%	350,300
1983	2,347,242	166,800	120,500	275,900	261,800-
	-0.9%	-18.6%	-20.7%	-17.0%	289,900
1984	2,222,027	176,800	135,000	329,200	305,400-
	-5.6%	+5.7%	+10.7%	+16.2%	341,000
1985	2,226,159	166,700	123,800	279,000	260,800-
	+0.2%	-6.1%	-9.0%	-18.0%	297,200
1986	2,363,756	163,300	124,900	294,800	269,300-
	+6.2%	-2.0%	+0.9%	+5.7%	320,400

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1) Percent change from previous year.
2) Actual number unknown, figure given is an estimate.

Table 3 . Angler use, effort, success, and harvest for Yellowstone National Park, 1973-86.

Year	Angler days	$\bar{x}$ length angler day	Total hours fished	Landing rate	Total fish landed	Creel rate	Total fish creeled	% of anglers satisfied with: Overall experience	% of anglers satisfied with: Numbers caught	% of anglers satisfied with: Sizes caught	Average length of landed fish (in.)	Mean expertise level[a]
1973	230,100	2.45	564,400	0.86	485,400	0.16	90,300	--	--	--	--	--
1974	220,000	2.42	531,300	0.86	456,900	0.19	101,000	--	--	--	--	--
1975	257,300	2.31	594,400	1.09	647,900	0.23	136,700	77	74	75	13.3	--
1976	284,200	2.36	670,700	1.02	684,100	0.20	134,100	74	69	69	13.2	1.90
1977	311,300	2.33	725,300	0.98	710,800	0.20	145,100	75	68	70	13.4	1.83
1978	333,800	2.23	744,400	0.99	736,900	0.17	126,500	73	66	68	13.4	1.86
1979[b]	291,300	2.49	725,300	1.01	731,100	0.15	107,300	73	67	68	13.6	1.88
1980	311,300	2.44	758,000	0.96	725,300	0.13	101,000	73	66	68	13.4	1.87
1981	383,400	2.41	923,000	0.93	844,700	0.12	110,800	73	65	66	13.4	1.88
1982	332,500	2.34	777,600	0.95	740,200	0.14	107,500	74	67	68	13.5	1.88
1983	275,900	2.36	652,100	0.95	622,400	0.11	71,600	76	69	68	13.6	1.89
1984	329,200	2.40	790,100	0.93	732,700	0.12	92,100	76	68	69	13.5	1.91
1985	279,000	2.47	688,500	0.92	629,700	0.10	69,800	76	68	71	13.3	1.90
1986	294,800	2.49	734,700	1.01	740,900	0.10	73,400	79	72	72	13.3	1.93

a) Based on: 1.0 = inexperienced angler, 2.0 = experienced, 3.0 = expert.
b) Revised from that reported in Jones et al. (1980).

Table 4. Characteristics of satisfied and unsatisfied anglers, and the influence of the relative expertise of anglers to sportfishing success in Yellowstone National Park, 1986.

	Mean number days fishing	Mean number hours fished per day	Landing rate	Creel rate	Fish landed per angler day	Fish creeled per angler day	Average length fish landed (in)	Average expertise[a]	Number of anglers sampled
Satisfied anglers		2.62	1.11	0.11	2.91	0.29	13.59	1.02	3,100
Unsatisfied anglers		2.29	0.53	0.05	1.21	0.11	11.31	1.88	1,069
sum or $\bar{x}$	1.81	2.49	1.01	0.10	2.51	0.25	13.31	1.93	4,816[b]
Inexperienced anglers	1.70	2.21	0.70	0.11	1.55	0.24	13.79	1.00	926
Experienced anglers	1.82	2.48	1.00	0.10	2.48	0.25	13.20	2.00	3,201
Expert anglers	1.97	2.96	1.22	0.07	3.61	0.21	13.77	3.00	599
sum or $\bar{x}$	1.81	2.49	1.01	0.10	2.51	0.25	13.31	1.93	4,816[b]

Satisfaction Matrix

	Satisfied Anglers			Unsatisfied Anglers		
	Overall satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed	Overall satisfaction	Satisfaction with numbers landed	Satisfaction with sizes landed
Landing Rate (Fish/hr)						
Inexperienced anglers	0.79	0.85	0.78	0.31	0.33	0.48
Experienced anglers	1.12	1.17	1.10	0.42	0.40	0.67
Expert anglers	1.30	1.32	1.22	0.74	0.68	1.25
Creel Rate (Fish/hr)						
Inexperienced anglers	0.13	0.13	0.12	0.04	0.05	0.07
Experienced anglers	0.12	0.12	0.11	0.04	0.05	0.07
Expert anglers	0.08	0.08	0.07	0.05	0.05	0.09
Fish Size (Inches)						
Inexperienced anglers	13.86	13.84	14.09	12.41	13.30	12.04
Experienced anglers	13.31	13.29	13.63	11.28	11.83	10.64
Expert anglers	13.94	13.88	14.37	11.77	12.44	10.92

a) Based on 1.0 = inexperienced angler; 2.0 experienced; 3.0 expert.

b) The averages are based on all anglers in the sample. Not all anglers marked satisfaction or expertise boxes therefore the sums of the columns do not add up to the total given.

127 mm (5 in). Since the mean length of all landed fish only declined 7 mm (0.3 in) from 1984 to 1985, it appears that overall effect of the change was not great. Mean length of brook trout, however, declined 23% (55 mm or 2.2 in), suggesting the added length categories have greatly improved the ability of the system to provide accurate statistics for a variety of species in widely differing habitats.

The percentage of anglers that reported satisfaction with their overall fishing experience was 79% in 1986. Satisfaction rates with numbers and sizes of fish landed both equaled 72% (Table 4). Anglers indicating satisfaction with their fishing trip landed 2.9 fish, but unsatisfied anglers landed only 1.2 fish. Average length of fish landed was also higher for satisfied anglers (345 mm or 13.6 in) than for unsatisfied anglers (287 mm or 11.3 in).

On the VAR card, anglers are asked to judge their own angling expertise level, and expertise is then estimated for each water by a mean index value as follows: 1.0 is an inexperienced angler, 2.0 is experienced, and 3.0 is an expert. In 1986, mean expertise for 4,816 park anglers was 1.93, indicating that most anglers fall into the inexperienced to experienced category (Table 4).

Comprehensive analyses of VAR data for several fisheries including Yellowstone Lake, the catch and release section of the Yellowstone River, Riddle Lake, Lamar River, Soda Butte Creek, Pebble Creek, Amphitheater Creek, Buffalo Creek, Plateau Creek, and Madison River were completed in 1986. Although it was not possible to expand these analyses to additional waters, data for 26 lakes and streams that made up over 95% of the total park angler use are given in tabular form (Tables 5 and 6).

Table 5. Fishery statistics from Yellowstone Park waters with over 40 angler days in the sample and which comprise over 95% of the parkwide angler day use in 1986.

	% of total parkwide angler days	Total reported angler days (VAR)	Estimates for the season								x̄ length fish landed (inches)	x̄ length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	% anglers satisfied with:		
			Anglers	x̄ length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creeled					Overall experience	Numbers caught	Fish sizes caught
Parkwide fishery	100.00	8,724	124,899	2.49	294,849	734,711	1.01	0.10	740,943	73,436	13.31	12.31	72	1.93	79	72	72
Yellowstone Lake	40.50	3,533	44,166	2.54	119,395	302,799	1.09	0.16	330,551	48,403	14.73	12.25	75	1.79	84	77	80
Yellowstone River	18.17	1,585	22,407	2.67	53,554	143,171	1.02	0.04	145,306	5,419	14.81	12.12	74	2.00	86	79	86
Madison River	5.42	473	7,158	2.48	15,968	39,598	0.57	0.03	22,549	1,130	12.38	16.88	53	2.07	59	52	52
Firehole River	5.19	453	6,613	2.23	15,292	34,164	0.76	0.02	25,836	571	10.11	15.44	65	2.05	69	56	46
Slough Creek	5.02	438	7,495	2.92	14,785	43,112	1.14	0.01	49,040	509	12.47	-	82	2.09	80	76	81
Gibbon River	3.84	335	6,406	1.91	11,304	21,563	0.90	0.06	19,485	1,393	8.17	10.00	65	1.98	62	52	44
Lewis Lake	2.72	237	2,982	2.90	7,992	23,141	0.54	0.15	12,524	3,389	13.79	14.50	46	2.00	73	61	72
Shoshone Lake	2.49	217	1,815	3.07	7,316	22,476	0.65	0.16	14,534	3,607	16.82	17.75	56	2.00	77	64	82
Lamar River	2.40	209	3,994	2.16	7,045	15,218	0.98	0.02	14,939	347	11.29	8.56	80	2.01	86	76	83
Gardner River	1.54	134	2,723	1.88	4,510	8,487	1.44	0.16	12,177	1,371	8.99	10.34	84	2.00	78	65	52
Soda Butte Creek	1.44	126	1,530	2.20	4,240	9,331	1.53	0.09	14,272	853	9.14	11.56	73	1.95	83	78	67
Lewis River	1.16	101	2,049	2.05	3,395	6,955	0.79	0.04	5,514	251	9.58	15.67	56	2.10	77	60	53
Falls River	0.89	78	1,193	2.11	2,618	5,532	0.79	0.13	4,359	698	8.52	10.24	61	1.80	58	58	42
Snake River	0.89	78	1,141	2.04	2,618	5,335	0.79	0.11	4,218	568	11.86	14.78	78	1.79	71	56	65
Gallatin River	0.72	63	1,011	2.08	2,111	4,386	0.88	0.08	3,854	368	11.49	11.12	81	2.18	59	59	71
Bechler River	0.69	60	882	2.86	2,009	5,752	0.75	0.08	4,335	482	11.31	12.30	78	2.12	62	52	52
Indian Creek	0.54	47	985	1.94	1,570	3,042	1.02	0.23	3,096	692	6.81	6.89	80	1.68	76	72	38
Nez Perce Creek	0.48	42	985	1.87	1,401	2,622	0.53	0.04	1,380	106	9.56	9.50	26	1.87	45	36	23

Table 6. Fishery statistics from Yellowstone Park waters with less than 40 angler days per year represented in the sample, 1986.

		Total	Estimates for the season												% anglers satisfied with:		
	% of total parkwide angler days	reported angler days (VFR)	Anglers	$\bar{x}$ length angler day (hours)	Angler days (trips)	Angler hours (effort)	Landing rate	Creel rate	Total fish landed	Total fish creeled	$\bar{x}$ length fish landed (inches)	$\bar{x}$ length fish creeled (inches)	% anglers landing 1 or more fish	Average expertise	Overall experience	Numbers caught	Fish sizes caught
Lewis Channel	0.36	31	622	2.58	1,029	2,653	0.67	0.18	1,772	464	13.84	14.67	72	2.14	100	76	88
Heart Lake	0.34	30	363	2.62	995	2,611	1.03	0.08	2,695	199	15.72	19.44	60	1.86	77	62	77
Trout Lake	0.33	29	389	3.14	961	3,022	0.52	0.10	1,560	301	13.64	15.93	12	2.00	67	67	75
Grebe Lake	0.29	25	519	2.01	826	1,661	0.82	0.04	1,353	75	8.70	15.00	67	2.00	63	63	56
Obsidian Creek	0.29	25	363	1.70	826	1,404	1.22	0.32	1,714	451	6.26	7.09	86	1.86	93	71	21
Middle Creek	0.28	24	311	1.77	792	1,400	0.55	0.12	773	167	9.21	11.00	44	1.92	89	78	56
Sylvan Lake	0.25	22	493	1.39	725	1,007	2.34	0.05	2,362	51	9.29	9.00	76	2.00	100	88	69

YELLOWSTONE LAKE

Throughout the past century, Yellowstone Lake has remained the most popular fishery in the park, and the lake supports the largest inland cutthroat trout population in the world. Despite a great surface area (35,400 ha or 87,450 acres) and once seemingly inexhaustable trout population, large scale spawn-taking operations, commercial fishing, and a 100-year history of almost unabated increases in sport fishery harvests have altered historical trout stocks from the original state. Managers have attempted to enhance and protect this unique resource, and regulations restricting anglers date back to the 1880's. From this early date until 1968, periodic reductions in the creel limit failed to have lasting positive effects, and angling success and the condition of the trout stocks declined (Gresswell 1980).

A 356 mm (14 in) minimum size (3 fish creel) restriction imposed in 1970 helped curb the intense overfishing which occurred during the 1950's and 1960's. Despite initial benefits, it soon became evident that rising effort and harvests and a rapid decrease of older and larger trout negated positive changes.

Beginning in 1975, regulations allowed the daily harvest of two trout under 330 mm (13 in) total length (TL). Theoretically, this regulation would take advantage of compensatory survival in younger age groups and improve the population age structure. With an increase of older and larger trout, the stability and productivity of multiple age spawning stocks would ideally resemble historic levels. This regulation has remained unchanged since 1975; however, it was 1978 before it was extended to lake tributaries.

In 1986, efforts to assess the response of the Yellowstone Lake cutthroat trout to the 330 mm maximum size limit continued. Studies included a creel survey utilizing the VAR system (Jones et al. 1977), and an experimental gillnetting program. Excessive spring runoff and high lake levels prevented the operation of the Clear Creek weir in 1986.

ANGLER USE

During 1986, angler use on Yellowstone Lake comprised 40% of the total parkwide angler use. An estimated 47,166 anglers spent 119,395 angler days and 302,799 angler hours fishing in the lake (Table 7). Use and

Table 7. Fishing statistics from Yellowstone Lake, 1986.

Yellowstone Lake area:		% of lake total	Total VFR use reported	Predicted totals for season								% Anglers satisfied with:			
				Anglers	$\bar{x}$ length angler day (hours)	Angler days (trips)	Angler hours	Landing rate	Creel rate	Total fish landed	Total fish creeled	Overall experience	Fish numbers	Fish sizes	Mean expertise
1	Shore	3.71	131	1,815	1.91	4,409	8,430	0.51	0.23	6,783	1,916	85	75	87	1.81
	Boat	1.90	67	674	2.87	2,246	6,436	2.16	0.27	13,910	1,734	92	88	77	2.08
2	Shore	29.15	1,030	13,901	2.04	34,795	70,896	0.69	0.13	49,220	9,066	75	66	75	1.78
	Boat	21.14	747	8,740	3.17	25,230	80,077	1.07	0.18	85,802	14,024	92	86	81	1.74
3	Shore	5.24	185	1,919	2.17	6,234	13,514	1.61	0.14	27,143	2,629	88	81	79	1.71
	Boat	1.19	42	726	3.08	1,401	4,319	1.11	0.19	4,806	812	96	88	77	1.70
4	Shore	10.39	367	5,161	1.95	12,386	24,194	0.77	0.13	18,697	3,142	77	72	79	1.81
	Boat	4.70	166	1,608	3.27	5,592	18,264	1.31	0.21	23,951	3,778	93	82	84	1.88
5	Shore	0.11	4	52	1.45	116	169	3.09	0.11	521	19	50	50	50	2.50
	Boat	3.03	107	1,167	2.66	3,598	9,553	1.80	0.17	17,160	1,660	100	100	97	1.81
6	Shore	---	0	---	---	---	---	---	---	---	---	---	---	---	---
	Boat	2.58	91	1,011	3.72	3,057	11,385	2.82	0.11	32,092	1,233	92	92	95	1.87
7	Shore	0.03	1	26	1.53	15	23	1.01	0.01	23	0	100	100	100	2.00
	Boat	0.65	23	207	2.21	759	1,675	2.27	0.20	3,805	329	100	100	80	2.00
Unknown shore		7.25	256	2,723	2.13	8,634	18,372	0.78	0.15	14,411	2,723	72	63	72	1.92
Unknown boat		8.94	316	4,435	3.27	10,662	34,837	1.33	0.20	46,284	7,008	92	84	83	1.74
All shore		55.87	1,974	25,597	2.04	66,702	135,807	0.82	0.14	111,771	18,745	77	69	77	1.80
All boat		44.13	1,559	18,569	3.17	52,675	166,942	1.38	0.19	230,708	30,624	93	87	83	1.78
Entire lake		100.00	3,533	44,166	2.54	119,395	302,799	1.09	0.16	330,551	48,403	84	77	80	1.79

effort estimates remained below the 11-year average since 1975 (140,800 angler days and 339,580 angler hours, respectively). These figures represent 7% and 9% increases, respectively, from 1985 (Figure 1).

Angler use continued to be most heavily concentrated in the accessible areas including the northwest portion of the lake, the West Thumb segment, western shoreline, and eastern shoreline. The central and southern areas sustained the lowest proportion of use (Table 7). Success continues to be inversely related to angling pressure; the more remote areas sustain higher landing rates than the more heavily fished accessible areas.

From 1969 through 1974, an average of 86% (range: 84%-88%) of angler use occurred in areas with easy access, but since the 330 mm maximum size limit was implemented in 1975, annual percentages have ranged from 89% to 94%, with a mean of 92%. The effect of the current regulation on this apparent shift in pressure is not clear. The accessible areas have smaller trout and thereby provide a greater chance of creeling a limit; however, changes in survey techniques since 1975 confound comparisons. Regardless of the reason, it has been the more accessible areas of the lake which have been historically overfished.

Yellowstone Lake anglers landed an estimated 330,600 trout and released 282,100. Total angler-caused mortality was estimated at 76,600 (48,400 creeled plus an estimated 28,200 which may have died of hooking wounds following release). Overall landing and creel rates were 1.09 and 0.16 trout/hour, respectively. The 1986 landing rate is the highest reported since 1950 when annual creel statistics were initiated; only a single estimate from 1941 (1.19 trout/hour) exceeded the 1986 estimate. Landing and creel rates from the boat segment (1.38 and 0.19 trout/hour, respectively) were significantly higher than those from the shoreline segment (0.82 and 0.14 trout/hour, respectively) (Table 7). Seventy-five percent of one-day anglers landed one or more trout from the lake, and 31% creeled one or more.

Based on length measurements of 16,281 trout reported from Yellowstone Lake, size structure of the cutthroat trout population appears to be approaching equilibrium (Table 8). Average size of landed trout in 1986 was 374 mm. Since 1975, length frequencies have indicated survival of proportionately more fish to older and larger size groups (Table 8). The percentage of landed

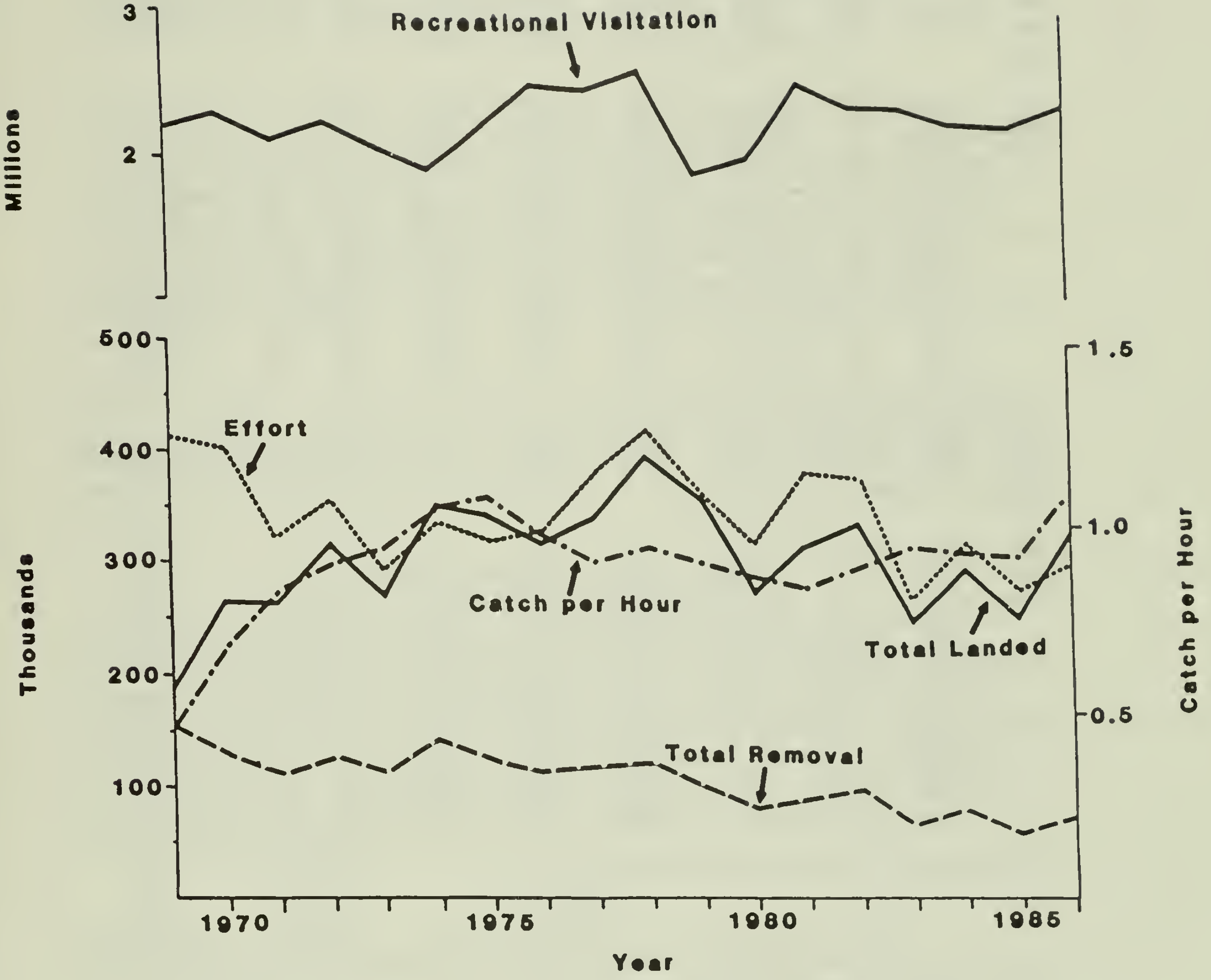

Figure 1 . Recreational visitation, catch per hour, total effort (hours), total trout landed, and total trout removed from Yellowstone Lake, 1969-86.

Table 8. Average length and length frequencies of cutthroat trout landed and creeled from Yellowstone Lake, 1973-86.

		Number and percentage of trout in length groups (inches):							
		<10	10-12	12-14	14-16	16-18	18-20	>20	N
Number of trout reported landed:									
14" min. size	1973	131	364	1,204	1,521	268	9	0	3,497
	1974	823	1,861	6,276	8,296	1,097	90	4	18,447
13" max. size	1975	686	2,634	8,654	8,366	1,571	155	44	22,110
	1976	816	3,415	10,160	10,123	2,295	349	94	27,252
	1977	645	3,029	10,068	11,778	3,619	613	228	29,980
	1978	1,174	3,878	10,322	14,794	4,523	728	188	35,607
	1979	781	2,463	7,042	13,193	5,308	912	237	29,936
	1980	295	1,500	5,418	8,855	3,268	699	212	20,217
	1981	356	1,646	5,112	8,670	3,570	569	131	20,054
	1982	771	2,702	9,909	9,965	4,186	736	226	24,495
	1983	543	1,760	4,446	7,362	3,632	891	308	18,942
	1984	552	1,955	4,536	6,666	3,367	655	213	17,944
	1985	491	1,001	3,520	6,723	2,885	669	182	15,471
	1986	345	1,121	3,818	7,126	2,864	825	182	16,281
Percentage of trout reported landed:									
14" min. size	1973	3.7	10.4	34.4	43.5	7.7	0.3	0.0	3,497
	1974	4.5	10.1	34.0	45.0	5.9	0.5	0.02	18,447
13" max. size	1975	3.1	11.9	39.1	37.8	7.1	0.7	0.2	22,133
	1976	3.0	12.5	37.3	37.1	8.4	1.3	0.3	27,252
	1977	2.2	10.1	33.6	39.3	12.1	2.0	0.8	29,980
	1978	3.3	10.9	29.0	41.5	12.7	2.0	0.5	35,607
	1979	2.6	8.2	23.5	44.1	17.7	3.0	0.8	29,936
	1980	1.5	7.4	26.8	43.8	16.2	3.3	1.0	20,217
	1981	1.8	8.2	25.5	43.2	17.8	2.8	0.7	20,054
	1982	3.1	11.0	24.1	40.7	17.1	3.0	0.9	24,495
	1983	2.9	9.3	23.5	38.9	19.2	4.7	1.6	18,942
	1984	3.1	10.9	25.3	37.1	18.8	3.7	1.2	17,944
	1985	3.2	6.5	22.8	43.5	18.6	4.3	1.2	15,471
	1986	2.1	6.9	23.5	43.8	17.6	5.1	1.1	16,281

		Percentage of trout landed measuring over:					Mean length landed		Mean length creeled	
		>12 in	>14 in	>16 in	>18 in	>20 in	in	mm	in	mm
14" min. size	1973	85.8	51.4	7.9	0.3	0.0	13.8	350	--	--
	1974	85.5	51.4	6.5	0.5	0.02	13.8	350	--	--
13" max. size	1975	84.9	45.8	8.0	0.9	0.2	13.7	349	12.4	316
	1976	84.8	47.5	14.1	2.0	0.3	13.8	350	12.4	314
	1977	87.8	54.2	14.9	2.8	0.8	14.2	360	12.6	319
	1978	85.8	56.8	15.3	2.6	0.5	14.2	360	12.4	314
	1979	89.2	65.6	21.6	3.8	0.8	14.6	370	12.4	316
	1980	91.9	64.3	20.5	4.4	1.0	14.6	371	12.6	320
	1981	90.0	64.5	21.3	3.5	0.7	14.6	370	12.5	316
	1982	85.8	61.7	21.0	3.9	0.9	14.4	366	12.2	311
	1983	87.8	64.4	25.5	6.3	1.6	14.7	372	12.2	309
	1984	86.0	60.8	23.6	4.8	1.2	14.5	367	12.3	313
	1985	90.4	67.6	24.1	5.5	1.2	14.7	372	12.2	311
	1986	91.0	67.5	23.8	6.2	1.1	14.7	374	12.2	311

trout exceeding 406 mm TL (23.8%) is substantially higher than before the regulation change. The percentage of landed trout measuring over 475 mm and 508 mm remain among the highest yet reported.

Like other fishing violations, the illegal harvest of trout over 330 mm is a continuing problem. An estimated 8,083 trout over 330 mm, including 1,065 over 356 mm, were creeled in 1986. The combination of strict law enforcement, increased public awareness, and acceptance of the 330 mm maximum size regulation have caused significant declines in the percentage of illegal trout harvested; however, the level of violations is still a concern.

During 1986, the percentage of anglers satisified with their overall angling experience on Yellowstone Lake was 84%; satisfaction with numbers and sizes landed was 77% and 80%, respectively (Table 7). Average expertise was 1.79.

LARGEMESH GILLNETTING

With the exception of 1973 and 1975, largemesh gillnetting has been conducted annually on Yellowstone Lake since 1969. The objective of this program is to monitor effects of angler harvest on relative abundance and population structure of cutthroat trout. Dean et al. (1970-75), Varley et al. (1976), and Jones et al. (1977-86) detail methods and provide summaries of previous results.

Methods

In 1986, experimental gillnets were set from 15 to 19 September at 11 sites in Yellowstone Lake (Figure 2). Field and laboratory sampling procedures remained identical to those described by Jones et al. (1985).

Results

Cutthroat Trout 1985

A total of 921 cutthroat trout were captured in 1986. Average number of trout captured per net was 16.7, and mean length, weight, and condition factor (K) were 293 mm, 274 g, and 0.86, respectively (Tables 9 and 10).

Number of trout captured per net differed significantly between the 11 netting sites (Appendix A Table 1). Highest numbers were captured at sites 1b, 4b, and 1c

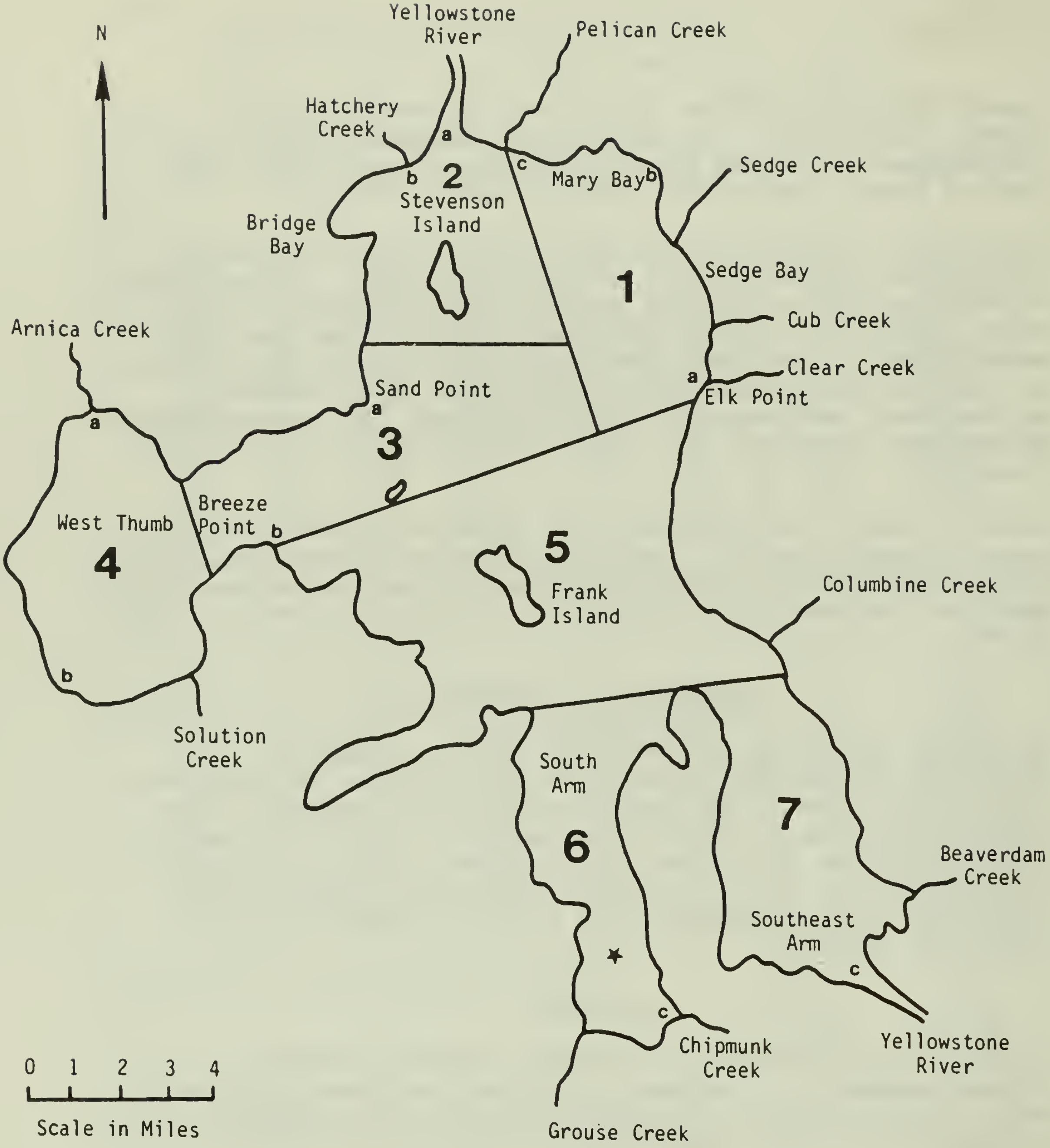

Figure 2. Creel survey, gillnetting, and plankton sampling (★), Yellowstone Lake, 1986.

Table 9. Length-frequency distribution, average lengths, weights, and condition factors of nonspawning and prespawning cutthroat trout and longnose suckers captured in largemesh gillnets, 1.5-4.6 m depth interval, Yellowstone Lake, 1986.

Species	Maturity category[1]	Size-group (lower length of interval - mm) 150	200	250	300	350	400	450	500	550	Total number	Average total length (mm)	Average weight (g)	Average condition factor (K)
Cutthroat Trout	Nonspawners	169	200	121	76	117	30	4			717	266	202	0.86
	Prespawning males		4	3	11	41	35	10			104	386	540	0.89
	Prespawning female				16	53	29	2			100	385	509	0.87
	TOTALS AND AVERAGES	169	204	124	103	211	94	16			921	293	274	0.86
Longnose Sucker	Nonspawners	27	80	85	52	2	1				247	258	212	1.10
	Prespawning males			24	67	46	57	3			197	363	620	1.22
	Prespawning females				4	25	40	46	9	1	125	438	952	1.12
	TOTALS AND AVERAGES	27	80	109	123	73	98	49	9	1	569	334	516	1.14

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1) Prespawning fish defined as those judged to have sufficient gonadal development to spawn in 1987; nonspawners include immature, and mature fish which were judged to lack sufficient gonadal development to spawn in 1987.

Table 10. Comparative largemesh gillnetting results, cutthroat trout, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-72, 1974, 1976-80, and 1982-86.

Year	Number of gillnet sets[1]	Average number trout per net	95% confidence interval of number trout/net	Mean length (mm)	% of trout over 356 mm (TL)	% of trout over 406 mm (TL)	% of trout over 457 mm (TL)	Percent of trout over 304 mm (TL) judged as prespawners	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)	Condition factor (K)
1969	9	12.22	±6.71	311	29.1	1.8	0.0	48	1.06:1	353	346	0.924
1970	11	12.27	±5.90	315	26.7	3.0	0.0	44	1.73:1	359	351	0.917
1971	5	14.40	±9.76	321	37.5	1.4	0.0	54	1.50:1	360	368	0.853
1972	11	13.63	±3.57	313	32.7	3.3	0.0	39	0.52:1	358	369	0.937
1974	11	15.45	±4.75	298	34.7	0.6	0.0	52	1.00:1	349	359	0.859
1976	11	15.00	±3.06	317	37.6	2.4	0.0	47	1.43:1	370	365	0.877
1977	44	15.55	±1.98	290	33.0	4.7	0.2	73	0.98:1	376	362	0.892
1978	55	13.93	±1.06	308	37.5	5.4	0.3	64	1.06:1	383	372	0.923
1979	55	13.60	±1.27	303	32.3	7.4	0.1	58	0.91:1	387	374	0.915
1980	55	13.00	±1.53	309	40.6	7.1	0.3	50	1.05:1	389	376	0.884
1982	55	10.60	±1.05	322	47.1	12.7	0.7	62	1.10:1	389	379	0.909
1983	55	18.05	±1.67	288	32.5	9.6	0.8	52	1.12:1	396	380	0.901
1984	54	19.50	±1.88	281	26.1	7.6	0.5	51	1.09:1	389	382	0.921
1985	55	14.30	±1.90	311	34.8	11.6	0.5	40	1.41:1	398	384	0.927
1986	55	16.75	±2.03	293	32.7	9.7	1.1	47	1.04:1	386	385	0.879

1) Number of sets has been limited to the 1.52-4.57 m depth interval to ensure comparability.

(26.2, 24.0, and 22.8 trout/net, respectively). Catches were lowest at sites 2a and 3b (8.6 and 7.0 trout/net, respectively).

There were no significant differences in the number of trout captured per net between the four lake zones (North: 1a, 1b, 1c, 2a, 2b; Central: 3a, 3b; West Thumb: 4a, 4b; South: 6c, 7c) (Appendix A Table 2). Numbers were greater for West Thumb and North (19.6 and 18.3 trout/net, respectively) than for South and Central (14.0 and 12.6 trout/net, respectively).

Mean length of captured trout differed significantly among sample sites (Appendix A Table 1). Average lengths were greatest at sites 6c, 1c, 7c, and 3b (338, 328, 328, and 327 mm, respectively), and lowest at sites 2b, 4b, 1b, and 4a (260, 265, 268, and 274 mm, respectively). Mean length of captured trout was not significantly correlated to number of trout captured per net.

Significant differences in mean length of captured trout also occurred among lake zones (Appendix A Table 2). Mean length was greatest in the South (332 mm) followed by Central (301 mm), North (289 mm), and West Thumb (268 mm).

Approximately 47% of all trout over 300 mm were categorized as prespawners (fish with sufficient gonadal development to spawn in 1987). Mean length and weight of cutthroat trout prespawners was 386 mm and 525 g, respectively; mean condition factor (K) was 0.88. Prespawner male:female ratio was 1.04:1. Although differences in mean length between male and female prespawners was not significant, males exhibited a much greater range of sizes (Table 9).

Longnose Suckers

Average length and weight were 334 mm and 516 g, respectively, for 569 longnose suckers captured in 1986 (Appendix A Table 3). Average condition factor was 1.14 (Table 11). Ligula intestinalis was observed in 3.5% of the captured suckers. No clipped or tagged suckers were noted.

Approximately 93% of all suckers over 300 mm were categorized as prespawners. Mean length and weight of longnose sucker prespawners was 392 mm and 749 g, respectively; mean condition factor (K) was 1.18. Prespawner male:female ratio was 1.57:1. The difference

Table 11. Comparative largemesh gillnetting results, longnose sucker, 1.52-4.57 m depth interval, Yellowstone Lake, 1969-72, 1974, 1976-80, and 1982-86.

Year	Number of gillnet sets1)	Average number suckers per net	95% confidence interval of number suckers/net	Mean length (mm)	% of suckers over 356 mm (TL)	% of suckers over 406 mm (TL)	% of suckers over 457 mm (TL)	Percent of suckers over 310 mm (TL) judged as prespawners	Prespawning male:female ratio	Average length of prespawning males (mm)	Average length of prespawning females (mm)	Condition factor (K)
1969	9	16.33	±10.65	365	66.0	29.2	6.1	90	1.28:1	382	419	1.207
1970	11	6.45	±5.01	393	83.1	59.2	12.7	97	0.08:1	386	440	1.235
1971	5	37.00	±42.17	316	34.0	17.8	2.7	91	2.00:1	357	417	1.207
1972	11	2.54	±1.29	335	42.9	28.6	7.1	82	2.00:1	378	428	1.205
1974	11	15.91	±5.92	370	69.7	29.1	5.7	97	1.28:1	372	415	1.215
1976	11	14.55	±5.36	389	80.6	44.4	7.5	93	1.07:1	387	425	1.227
1977	44	7.25	±1.83	401	80.9	55.5	14.7	99	1.48:1	390	441	1.229
1978	55	7.25	±1.99	363	58.3	38.9	11.1	90	1.13:1	385	435	1.187
1979	55	12.64	±2.07	371	62.6	45.2	13.0	88	0.99:1	399	440	1.197
1980	55	9.98	±1.82	365	59.3	39.4	12.6	97	1.12:1	370	432	1.171
1982	55	8.64	±2.13	356	51.1	37.2	12.5	89	0.95:1	373	438	1.209
1983	55	11.36	±1.87	341	50.1	36.5	12.8	93	1.21:1	381	442	1.183
1984	54	13.65	±2.29	349	55.2	39.3	14.0	95	0.92:1	386	439	1.059
1985	55	6.20	±1.61	362	57.6	43.3	13.5	94	1.39:1	373	441	1.228
1986	55	10.35	±2.80	334	38.5	25.7	8.4	90	1.57:1	363	438	1.145

1) Number of sets has been limited to the 1.52-4.57 m depth interval to ensure comparability.

in mean length between male (363 mm) and female (438 mm) prespawners was significant. Males ranged from 265 to 470 mm, and females varied between 320 and 552 mm.

Discussion

Although the experimental design of the largemesh gillnetting program has been modified since the program began in 1969, data are comparable for 15 of 16 years in which studies have been conducted. Significant differences in efficiency were found between nets used in 1981 and those used in all other years (Jones et al. 1982); therefore, data from 1981 have been deleted to prevent confounding comparisons between years.

Cutthroat Trout 1969-86

Relative abundance and distribution. Mean number of trout captured per net has varied significantly since 1969 (Table 10), but when data were grouped by pre-330 mm maximum size limit (1969-74; mean = 13.6 trout/net) and post-regulation (1976-86; mean = 14.9 trout/net) periods, the difference between periods was not significant. There is, however, a significant correlation (r=0.65) between the percentage of trout less than 203 mm captured annually in gillnets and the mean number of trout captured per net per year. This relationship suggests that the total number of trout captured each year in gillnets is influenced by the relative abundance of age-1 and age-2 trout. Such annual fluctuations caused by variations in year-class strength confound the interpretation of impacts due to angler harvest; however, they have provided some ability to predict cutthroat trout recruitment prior to entry into the fishery.

The combined data from 15 years of gillnetting yielded significant differences between the 11 sample sites in the mean number of trout captured per net. Mean number per net continued to range between 16 and 17 for sites 1b, 1c, 2b, 3a, and 4b, and from 11 to 14 at sites 1a, 2a, 3b, 4a, 6c, and 7c. Differences between lake zones in the mean number of trout captured per net were not significant. Numbers captured in North, West Thumb, and Central were approximately 15 trout/net; Soutn yielded a mean of 13 trout/net. Between site differences are apparently due to factors other than the portion of the lake sampled, and variability between nets in the number of trout captured continues to reduce the sensitivity of comparisons.

Population structure. Mean length of trout captured in largemesh gillnets has varied significantly since 1969 (Table 10). Similar results were obtained when data were combined over years and compared by site and zone (Appendix A Tables 1 and 2). A significant correlation (r=-0.89) between the percentage of trout less than 203 mm and the mean length of all trout captured in gillnets probably reflects year-class fluctuations of age-1 and age-2 trout.

Because mean length of prespawners is unaffected by the proportion of smaller trout captured in gillnets, comparisons of prespawners can be used to detect length changes in mature trout. Although mean length of prespawners declined somewhat from 1985, the current mean length is the third highest reported since 1969. Mean length of prespawners since implementation of the 330 mm maximum size limit (382 mm) has increased 25 mm from the mean of pre-regulation years (1969-74; mean = 357 mm). In 1986, female prespawners displayed the highest mean length yet recorded; however, mean length of male prespawners acutally declined in 1986.

Analysis of length data based on the prespawner maturity category has definitely reduced factors which confound interpretation; however, this technique is based on subjective criteria for stage of maturity, especially for male cutthroat trout. Anderson (1976) introduced a technique of length frequency analysis based on Proportional Stock Density (PSD) or the proportion of a stock which is greater than or equal to a specific length. The specified length was termed "quality length"; however, both stock and quality lengths varied with species (Anderson 1978). Anderson and Weithman (1978), Anderson (1980), and Gabelhouse (1984) defined minimum stock and quality lengths for numerous species based on percentages of world record lengths.

More recently, Anderson (1980) defined Relative Stock Density (RSD) as the percentage of any defined size group within the stock of a particular species. In an attempt to refine the length-categorization system, Gabelhouse (1984) proposed the terms "preferred", "memorable", and "trophy" to describe length categories with minimum lengths of 45-55%, 59-64%, and 74-80% of world record lengths, respectively, and provided minimum size estimates for 69 species. Stock, quality, and preferred lengths suggested by Gabelhouse (1984) were 198-257 mm, 356-406 mm, and 447-543 mm, respectively for cutthroat trout.

Gillnetting data since 1969 were compared using 203 mm, 381 mm, and 457 mm for stock, quality, and preferred lengths, respectively. The calculated PSD for the pre-regulation period ranged from 7.04 to 13.71, with a mean of 10.91 (Figure 3). During that period RSD-preferred values equaled 0.0 in all years. Since the implementation of the 330 mm maximum size limit (1975), both PSD and RSD-preferred estimates have risen significantly. PSD estimates ranged from 18.13 (1977) to 31.79 (1982); mean PSD was 24.2, over twice the pre-regulation mean. RSD-preferred values rose to 1.34 in 1986, and the mean since 1976 was 0.54. These shifts toward larger trout suggest a greater survival of older trout in Yellowstone Lake under the 330 mm maximum size limit.

There has also been a decline since 1975 in the relative abundance of captured trout between 206 and 330 mm. This decrease may be related to the fact that approximately 66% of all creeled trout from Yellowstone Lake are between 203 and 330 mm. Although this effect appears to be compensated for by increased survival of remaining trout (as evidenced by increase in the proportion of larger trout), this apparent manifestation of harvest should be monitored closely in the future.

Longnose Suckers 1969-86

Average number per net. Although differences between years in the average number of suckers captured per net are significant (Table 11), reasons for these changes remain unidentified. It is doubtful these differences are due to population fluctuations since the longnose sucker is believed to be long-lived in Yellowstone Lake (Jones et al. 1977). These fluctuations may be partially due to schooling behavior; such behavior would intensify variation in the gillnet catch.

Average size. Comparisons between years (Table 11) yield significant differences in mean length. Mean length of suckers has been inversely correlated to the male:female ratio (r=-0.78) and directly correlated to the percentage of suckers over 310 mm (r=0.94) (Jones et al. 1981). Since the latter two factors are probably related to distribution, annual variations affecting numbers captured may also affect variations in mean length.

The largemesh gillnetting program has provided only minimal information concerning the longnose sucker. Although a more suitable method of monitoring the sucker

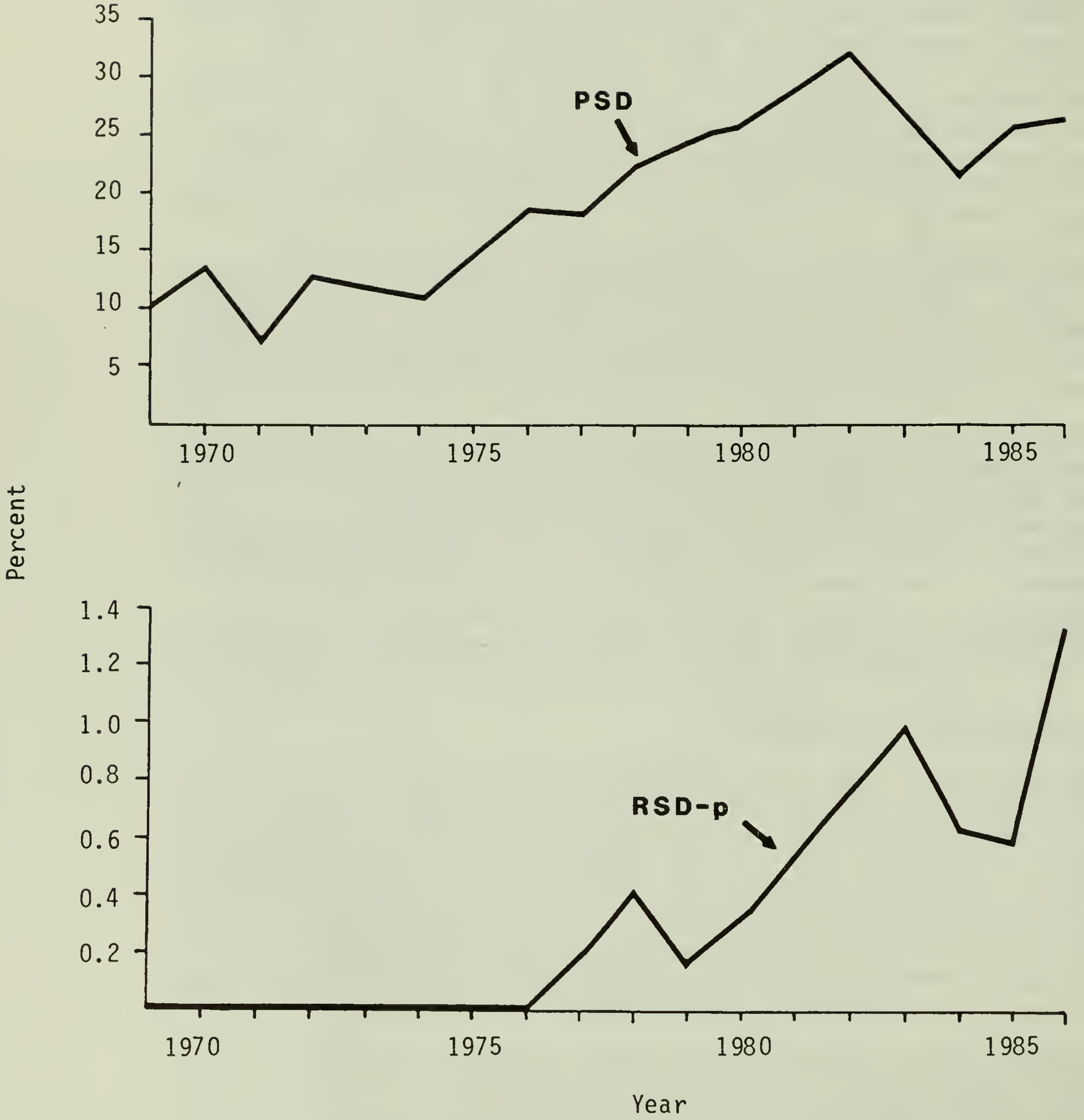

Figure 3 . Proportional Stock Density (PSD) and Relative Stock Density-preferred (RSD-p) for gillnet captured cutthroat trout, Yellowstone Lake, 1969-86.

population might be developed, an increasing amount of evidence suggests that the longnose sucker and cutthroat trout are probably not competing either temporally or spatially in Yellowstone Lake (Gresswell and Varley 1986). It would be more beneficial, therefore, to channel future effort to further describing the relationship between the two species.

CONCLUSIONS

It appears that the 330 mm maximum size limit is accomplishing the objective of increasing the proportion of older and larger cutthroat trout in Yellowstone Lake. Scattered historic size data and current estimates utilizing the Walford line (Ricker 1975) suggest a maximum of 11 age groups prior to modern angler exploitation.

Since Ricker (1963) has stated that exploitation as low as 5% annually may significantly alter a pristine population, the cutthroat trout population may never reach historic levels under current regulations. It is apparent, however, that the 330 mm maximum size limit has been more successful at approaching historic levels than any regulations utilized thus far. Average lengths of trout landed in the fishery and prespawners in fall-set gillnets are among the greatest yet recorded (Figures 4 and 5). Fecundity estimates suggest that current reproductive potential in Clear Creek is five times greater than it was during the 1950's (Jones et al. 1985).

What may be as important as the shift in population structure is that these changes are occurring while use (in the range of 150,000 angler days annually) and effort (over 350,000 angler hours) remain high. Despite these levels of pressure, landing rate has been excellent, averaging 0.94 trout/hour since 1975. Continued decrease in creel rate during this period is indeed curious, but data indicate that it is not related to a depletion of legal size trout. Increased popularity of catch and release fishing may be responsible for the decline in harvested trout.

The biological response to altered harvest patterns associated with the 330 mm maximum size regulation are not completely understood at present, but harvesting trout prior to maturity shifts fishing mortality to life stages which may better be able to withstand high levels of exploitation. The relatively short period that trout are vulnerable to harvest in Yellowstone Lake may also

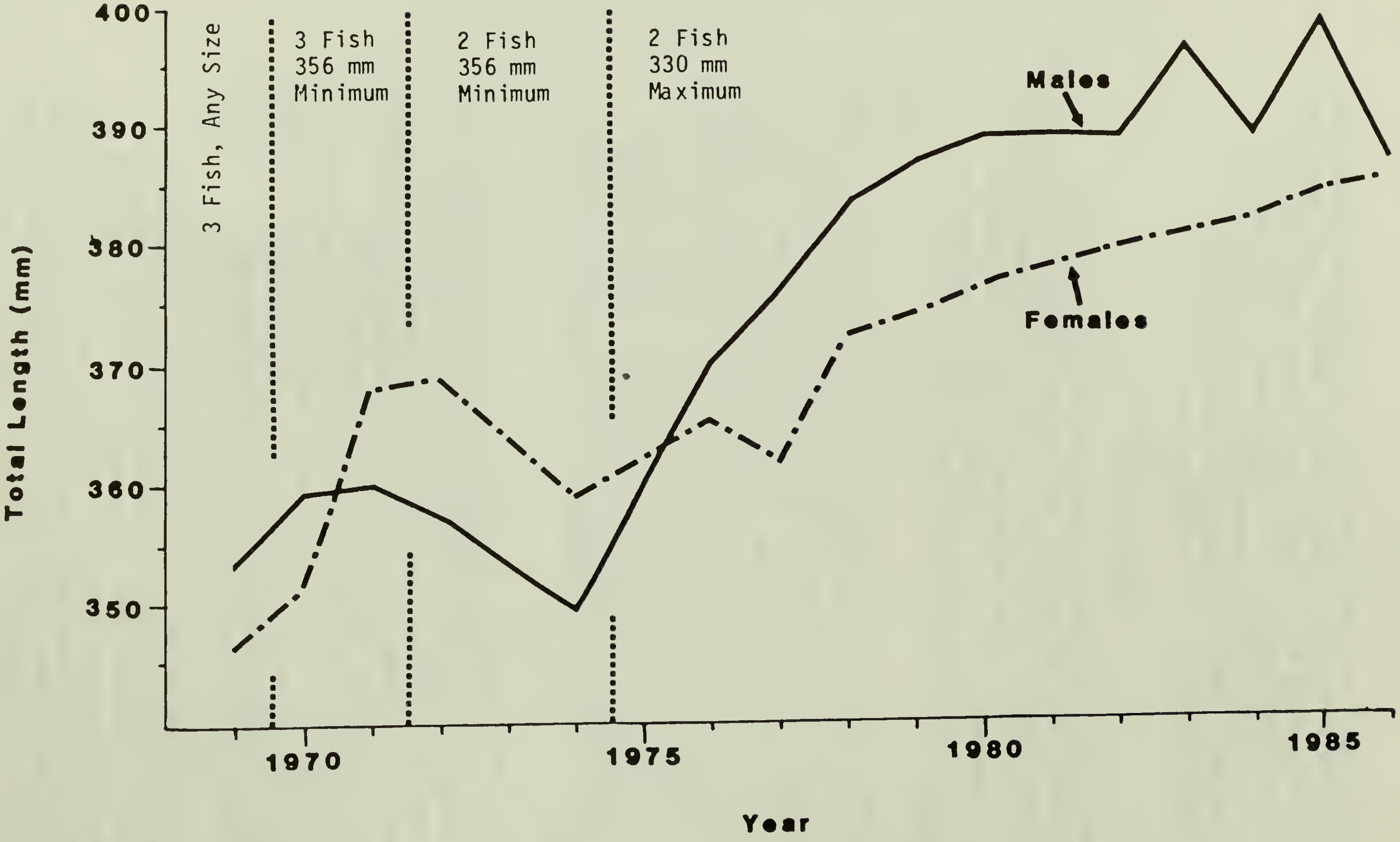

Figure 4 . Mean total length of prespawning cutthroat trout captured in largemesh gillnets, Yellowstone Lake, 1969-86.

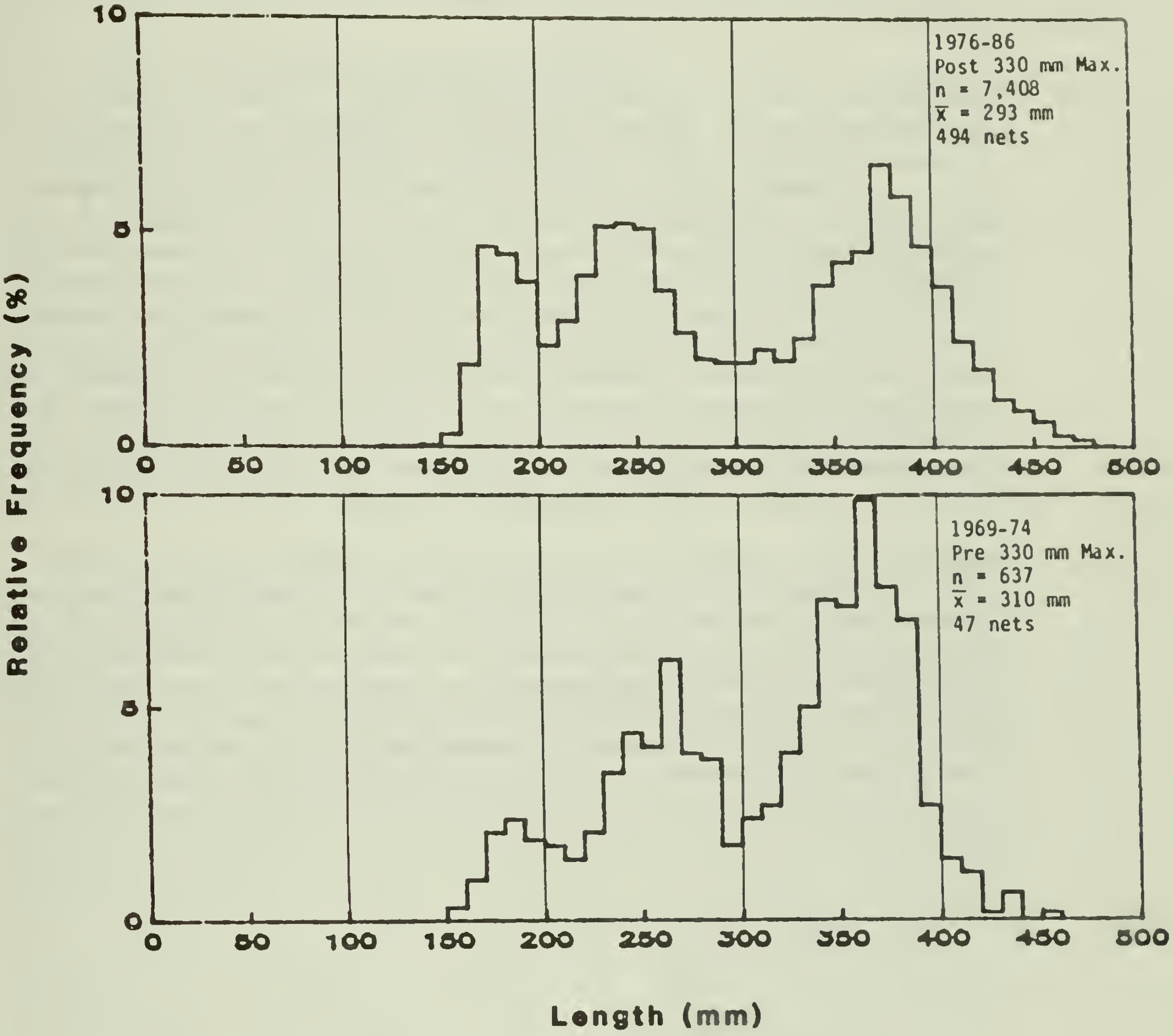

Figure 5. Length frequencies of cutthroat trout captured in largemesh gillnets at the 1.5-4.6 m depth interval in Yellowstone Lake, 1969-86 (excluding 1981).

influence results. Most trout do not enter the fishery until approximately 300 mm and are beyond the legal limit within one growing season.

As angler use and effort steadily increased, creel limits as low as three trout per day failed to protect the structure of this cutthroat population. Fishing closure or "no kill" (catch and release) regulations would undoubtedly provide maximum protection; however, the 330 mm maximum size limit not only provides substantial protection, but allows a daily creel limit which satisfies most anglers. Currently five large trout (356-457 mm) are captured and released for each trout under 330 mm creeled. Over two-thirds of all anglers catch one or more trout, and over one-third creel one or more. Excellent landing rates, often associated with "no kill" regulations, have been sustained while anglers have retained the privilege of harvesting trout for a campfire meal.

Results from the Yellowstone Lake fishery during the first 12 years of the 330 mm maximum size limit are indeed encouraging; however, it should be emphasized that these results may not describe an equilibrium condition. Future increases in angler use may affect the cutthroat trout population despite the protection afforded under the current regulation. Continued research is essential to the evaluation of the 330 mm maximum size limit, especially under higher levels of use.

CUTTHROAT TROUT SPAWNING ACTIVITY IN TRIBUTARIES OF YELLOWSTONE LAKE: LAKE AREA TO GRANT VILLAGE

INTRODUCTION

Cutthroat trout (Salmo clarki bouvieri) in Yellowstone Lake are adfluvial, and spawning in lake tributaries generally extends from May through July. Most investigations of cutthroat trout spawning activity in Yellowstone Lake tributaries have been conducted on eight streams: Pelican Creek, Cub Creek, Clear Creek, Columbine Creek, Chipmunk Creek, Grouse Creek, Arnica Creek, and Hatchery Creek. Hoskins (1974, 1975) first attempted to examine cutthroat trout spawning in all lake tributaries while studying grizzly bear (Ursus arctos horribilis) predation on spawning trout. He identified streams in which spawning occurred, and streams which were actively "fished" by bears.

In 1985, a cooperative study was initiated by the U.S. Fish and Wildlife Service (USFWS) and Interagency Grizzly Bear Study Team (IGBST) to gain a greater understanding of cutthroat trout spawning activity and bear-fish relationships in Yellowstone Lake tributaries. Objectives established by the USFWS included verifying tributary locations, determining which streams were used by spawners, monitoring seasonal patterns of spawning migrations, estimating the relative magnitude and population structure of spawning runs, and describing physical characteristics of spawning streams. The IGBST evaluated spawning trout as a food source for grizzly bears, quantified physical stream characteristics, and attempted to identify if bear-fish relationships had changed in the area since 1974-75. Jones et al. (1986) and Reinhart and Mattson (1986) summarize data collected by the USFWS and IGBST, respectively, in 1985.

In 1986, objectives addressed by the USFWS were identical to those established in 1985, with the exception that sampling was limited to Yellowstone Lake tributaries between Lake Area and Grant Village (Figure 6) (Appendix A Table 4). Only limited data had been collected on these streams in 1985, and the USFWS required more detailed information in order to address two development-related issues. First, the National Park Service (NPS) has proposed that some visitor facilities scheduled to be removed from the Fishing Bridge area be relocated at one or more locations along the lakeshore between Lake Area and Grant Village. Second, accurate information about the spawning runs in Grant Village was needed by the NPS as an aid in

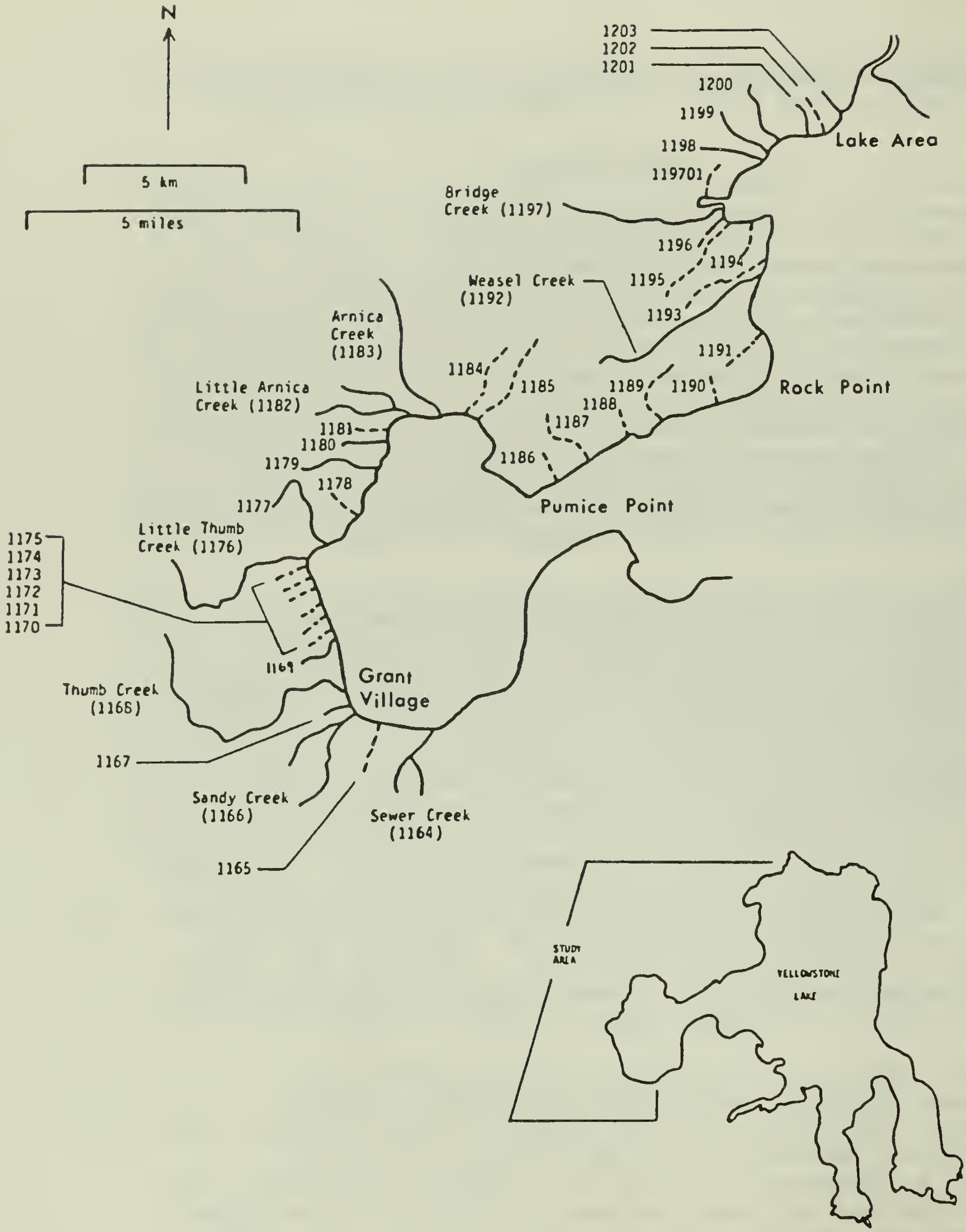

Figure 6 . Yellowstone Lake tributaries: Lake Area to Grant Village
(——— denotes tributaries where spawning was observed in 1986)
(– – – – denotes tributaries where no spawning was observed in 1986)
(–·–·– denotes streams not found in 1986).

determining an opening date for the Grant Village campground. In 1986, the IGBST also sampled streams in this area, as well as other tributaries to Yellowstone Lake which were known or suspected to be "fished" by grizzly bears. Reinhart and Mattson (1987) detail information obtained by the IGBST.

Study Area

The study area extended from Lake Area south to Grant Village (Figure 6) (Appendix A Table 4). All streams in this area flow under park roads before reaching the lake and are accessible by motor vehicle; thus, human activity in the roadside portions of these streams is generally greater than in other lakeshore areas. Tributaries of Yellowstone Lake are closed to angling during most of the spawning season (until 15 July) to minimize disturbance of spawning activity.

Methods

Cutthroat trout spawning activity was monitored from 8 May to 1 August 1986. United States Geological Survey Maps (scale 1:62,500) modified by Hoskins (1974) and USFWS (unpublished data) were used to help locate streams.

Tributaries that appeared to have the potential to support a spawning run were visited weekly until the presence or absence of spawning was visually confirmed, but tributaries categorized as unusable for spawning were not sampled. In each stream where spawners were found, except Arnica Creek, a 100-m long sample section was established within 1 km of the stream mouth, and weekly sampling of fish and physical stream characteristics continued until spawning was completed. Arnica Creek was not sampled due to its relatively large size. Techniques used in 1986 to sample spawning cutthroat trout and measure physical stream characteristics were identical to those used in 1985 (Jones et al. 1986).

Results

Available information regarding stream locations in Yellowstone National Park (USFWS unpublished data) shows that there are 41 tributaries to Yellowstone Lake between Lake Area and Grant Village (Figure 6) (Appendix A Table 4). Five streams were not found by the study team in 1986 (Figure 6) (Appendix A Table 5). Hence, only 36 tributaries were examined for cutthroat trout spawning activity.

No spawning was observed in 18 tributaries (Figure 6) (Appendix A Table 6). Twelve of these were categorized as unsuitable for spawning due to excessively low discharge, substrate composed largely of fines, and/or excessively high gradient. Four other tributaries had natural physical and/or chemical barriers at the stream mouth, and a man-made barrier (a road culvert) blocked upstream migration at the mouth of another stream (Hotel Creek). One tributary that appeared suitable for spawning was not used by cutthroat trout in 1986; reasons for this anomaly are unknown.

Spawning by adfluvial cutthroat trout was observed in 18 streams (Figure 6) (Appendix A Table 7). Two spawning streams were found in the Lake Area, five were located between the Lake Area and Rock Point, but none were found between Rock Point and Pumice Point. From Pumice Point to Grant Village, seven spawning streams were found, and four were located within Grant Village.

Physical stream characteristics measured in sample sections of 17 spawning streams (Table 12) revealed that most of these streams were narrow (mean width < 2 m), shallow (mean depth < 0.14 m), and had low discharge (mean discharge < 0.09 m^3/s). Gradients ranged from 1% to 5%, and substrates were largely composed of gravel and cobble. Undercut banks, deadfall, overhanging vegetation, and pools provided cover for spawning trout. Mean water temperatures ranged from 10 to 16 C.

Onset of spawning ranged from the last week of May through the third week of June in 15 tributaries for which reliable data were available (Table 13). In 11 of these streams, spawning began as streamflows subsided from peak spring runoff and water temperatures approached 7 to 10 C. Peak periods of spawning, estimated for only 11 tributaries (Table 13), occurred within the first 3 weeks of June. In all but two of these streams, spawning peaks were observed within the first 2 weeks of the spawning run. Spawning run duration, measured in 15 streams (Table 13), ranged from 4 to 8 weeks. Spawning was completed in most tributaries sampled by 12 July (Table 13).

A total of 1,108 cutthroat trout spawners were captured by electrofishing in 1986 (Table 14). Mean length of all captured spawners was 353 mm. Mean length of males (352 mm, n=652) was similar to that of females (354 mm, n=456). The sex ratio was 1.43 males:1 female.

Table 12. Physical stream characteristics measured in 100-m long sample sections of 17 Yellowstone Lake tributaries between Lake Area and Grant Village, 1986.

Stream Number	Stream Name	Dates Sampled	Mean Width (m)	Mean Depth (m)	Mean Discharge (m^3/s)	Mean Water Temperature (C)	Gradient (%)	Dominant Substrate Type[a)]	Cover Types[b)]
1203	-	6/10,16,23;7/1	1.0	0.13	0.0335	10.4	1	F/G	U/P/D/O
1201	Hatchery Creek	6/10,17,23;7/1	0.9	0.08	0.0251	11.4	3	G/C	U/P/D/O
1200	-	6/11,18	0.9	0.10	0.0246	9.8	5	G/C	O
1199	-	6/11,18,23;7/1	0.9	0.13	0.0373	11.9	4	G/C	O
1198	Wells Creek	6/11,17,23;7/1	0.9	0.11	0.0229	14.0	4	G/C	U/P/D/O
1197	Bridge Creek	6/11,18,23;7/1	1.3	0.18	0.0821	16.0	2	G/C	U/P/D/O
1192	Weasel Creek	6/12,17,23	0.9	0.12	0.0154	13.3	2	F/G	U/P/D/O
1182	Little Arnica Creek	6/12,18,23;7/1,8	1.9	0.17	0.1469	12.9	2	G	U/P/D
1180	-	6/18,23;7/1	0.6	0.12	0.0077	10.6	4	F/G/C	U/P/D/O
1179	-	6/17,23;7/1	1.0	0.13	0.0413	9.9	4	G	U/P/D
1177	-	6/18,25;7/2,9	1.3	0.11	0.0392	10.9	2	G	U/P/D/O
1176	Little Thumb Creek	6/18,25;7/2,9,16,25 8/1	1.9	0.11	0.0654	10.2	1	G	U/P/D
1169	-	6/20,26;7/2,9	2.2	0.12	0.0390	10.3	2	G/C	U/P/D/O
1168	Big Thumb Creek	6/13,19,25;7/2	3.8	0.18	0.5721	12.7	1	G/C	U/P/D
1167	-	6/4,12,19,26	1.5	0.10	0.0820	13.9	4	G	U/P/D
1166	Sandy Creek	6/4,13,19,26;7/2	2.2	0.16	0.3101	12.5	2	F/G	U/P/D
1164	Sewer Creek	6/19,26;7/2,9	1.2	0.08	0.0119	13.9	2	G/C	U/P/D

a) Substrate Codes: F = Fines (<2 m diameter), G = Gravel (2-65 mm diameter), C= Cobble (65-256 mm diameter).
b) Cover Codes: U = Undercut Bank, P = Pools, D = Deadfall, O = Overhanging vegetation.

Table 13. Observed dates of first and last spawning, duration of spawning run, and estimated peak period of spawning in 17 Yellowstone Lake tributaries between Lake Area and Grant Village, 1986.

Stream number	Stream name	Date spawning first observed	Date spawning last observed	Approximate duration of spawning run (weeks)	Estimated peak period of spawning
1203	-	5-29	7-1	6	-
1201	Hatchery Creek	5-25	6-23	5	-
1200	-	6-3[a]	6-18	-	-
1199	-	6-3[a]	7-8	-	-
1198	Wells Creek	6-3	7-1	5	6/3-14
1197	Bridge Creek	6-3	7-1	5	6/3-14
1192	Weasel Creek	6-12	6-30	4	6/12-14
1182	Little Arnica Creek	5-27	7-8	7	6/15-21
1180	-	6-13	7-1	4	6/13-21
1179	-	6-13	7-1	4	6/13-21
1177	-	6-13	7-9	5	6/13-21
1176	Little Thumb Creek	6-18	8-1	7	6/29-7/5
1169	-	6-13	7-9	5	-
1168	Big Thumb Creek	6-13	7-8	5	-
1167	-	6-4	6-26	4	6/4-14
1166	Sandy Creek	6-4	7-25	8	6/4-14
1164	Sewer Creek	6-13	7-9	5	6/13-21

a) Indicates spawning was in progress when stream first visited.

Table 14. Catch statistics for 17 Yellowstone Lake spawning tributaries sampled by electrofishing between Lake Area and Grant Village, 1986.

Stream Number	Stream Name	Dates When Fish Were Captured	Number of Spawners Captured	Mean Length (mm)	Number of Males	Mean Length (mm)	Number of Females	Mean Length (mm)	Male:Female Ratio
1203	-	6/10,16,23;7/1	60	344	37	339	23	353	1.61:1
1201	Hatchery Creek	6/10,17,23	86	358	48	358	38	358	1.26:1
1200	-	6/11,18	No Spawners Captured Within Sample Section						
1199	-	6/11,23;7/1	13	333	8	327	5	342	1.60:1
1198	Wells Creek	6/11,17,23;7/1	93	357	51	355	42	359	1.21:1
1197	Bridge Creek	6/11,18,23	54	358	28	360	26	356	1.08:1
1192	Weasel Creek	6/12,17,23	28	337	19	325	9	360	2.11:1
1182	Little Arnica Creek	6/12,18,23	46	372	33	377	13	359	2.54:1
1180	-	6/18,23	14	346	10	342	4	356	2.50:1
1179	-	6/17,23	45	365	32	367	13	360	2.46:1
1177	-	6/18,25;7/2,9	118	352	67	352	51	353	1.31:1
1176	Little Thumb Creek	6/18,25;7/2,9,19,25	213	350	117	348	96	352	1.22:1
1169	-	6/20,26;7/2,9	76	341	51	335	25	352	2.04:1
1168	Big Thumb Creek	6/20,25	71	352	31	361	40	345	0.77:1
1167	-	6/12,19,26	69	357	42	357	27	356	1.56:1
1166	Sandy Creek	6/13,19,26;7/2	44	356	28	357	16	353	1.75:1
1164	Sewer Creek	6/19,26;7/2	78	356	50	352	28	363	1.79:1
Totals and Averages			1,108	353	652	352	456	354	1.43:1

It was not possible to accurately estimate magnitude of spawning runs, and no statistically significant correlations were found between spawning data and measured physical stream characteristics.

Discussion

Current USFWS maps (USFWS unpublished data) show 124 tributaries to Yellowstone Lake. Field surveys conducted in 1985 (Jones et al. 1986; Reinhart and Mattson 1986) and 1986 have not found 11 tributaries (Appendix A Table 8). Locations of these 11 streams should be verified so that accurate maps can be maintained.

Jones et al. (1986) reported that cutthroat trout spawners have been observed in 68 Yellowstone Lake tributaries; however, it appears that only 52 of these streams may annually be used as spawning streams (Hoskins 1974, 1975; Jones et al. 1986). Of the 16 streams in which spawning may not occur annually (Appendix A Table 9), stream discharge in some may not be sufficient for spawning during low-water years. Fish may be prevented from ascending other streams during low-water years when stream mouths are blocked by beaches built up by wave action or when lake levels are not high enough to allow fish passage through some road culverts.

Although spawning in 1986 began about 2 weeks later than in 1985, seasonal patterns of spawning migrations observed in 1986 were fairly typical of Yellowstone Lake tributaries. Spawners entered tributaries as streamflows declined from peak runoff and as water temperatures approached 10 C. Peak periods of spawning for most tributaries occurred within the first 2 weeks of the spawning run, and spawning run durations tended to be longer in the larger streams. Spawning in all streams sampled was completed by the end of July.

It has become apparent that two factors have prevented obtaining usable estimates of spawning run magnitude. First, electrofishing usually began 1 week after visual confirmation of spawning in a stream; since field observations indicated that peak spawning often occurred within the first 2 weeks of a spawning run, pertinent data were not collected. Second, electrofishing efficiency declined as stream size increased; thus, relative estimates of run size in a stream could reflect electrofishing efficiency rather than numbers of fish using a stream. In the future, methods such as enumerating upstream fish migration past a weir or conducting periodic visual counts of spawners within a stream may be used to estimate spawning run size.

In this study and in 1985 (Jones et al. 1986), mean length of males was less than that of females, and sex ratios have strongly favored males. These results do not agree with data collected at spawning traps on other Yellowstone Lake tributaries (Ball and Cope 1961; Jones et al. 1978-85). Relationships observed at the spawning traps are probably more representative of those that actually occur in spawning runs in tributaries of Yellowstone Lake since data at spawning traps is collected systematically throughout the spawning season (Jones et al. 1986). One factor that may account for sex ratios and mean length comparisons observed in 1985 and 1986 is that males tend to remain in the stream longer than females (Ball and Cope 1961). Thus at any point during the spawning run, there may be more males in the stream, and any instantaneous sample taken will reflect this instream sex composition.

CONCLUSIONS AND RECOMMENDATIONS

During the 2 years this study has been in progress, most Yellowstone Lake tributary locations have been verified, tributaries used by spawners have been identified, and seasonal patterns of spawning migrations have been described by lake area and for many individual streams. Future work should include developing techniques to successfully estimate the relative magnitude of spawning runs, accurately determine population structure characteristics, and relate physical stream characteristics to spawning run dynamics. Ultimately, results from this study can be combined with existing data to estimate the status of each tributary as a spawning stream for adfluvial cutthroat trout from Yellowstone Lake.

ARNICA CREEK RESTORATION PROJECT

Arnica Creek is a tributary to Yellowstone Lake in the northern portion of West Thumb (Figure 7). With over 44 km of flowing water, the creek lies within the largest stream drainage (5,471 ha) in West Thumb. Arnica Creek empties into a 23.6 ha lagoon, which is generally open to the lake except for prolonged dry periods during late summer (Welsh 1952).

Yellowstone Lake supports what may be the largest remaining population of native inland cutthroat trout (Salmo clarki bouvieri) in the world. From May through July, cutthroat trout spawners ascend up to 69 tributaries to Yellowstone Lake (See Yellowstone Tributaries; this report). Arnica Creek sustains one of the larger spawning migrations (Ball and Cope 1961), and Benson (1961) reported that an average of 4,400 cutthroat trout entered the stream annually between 1951 and 1958. Arnica Creek was studied intensively from 1950 to 1961 (Welsh 1952; Cope 1956, 1957; Benson 1960; Ball and Cope 1961; Bulkley 1961; Benson and Bulkley 1963).

One other native fish (longnose dace Rhinichthys cataractae) and three introduced fishes (redside shiner Richardsonius balteatus, lake chub Couesius plumbeus, and longnose sucker Catostomus catostomus) also occur in Yellowstone Lake, and all five fish species have been collected in the Arnica Creek Lagoon since the late 1950's (Biesinger 1961). With the exception of the lake chub, these fishes have also been collected from Arnica Creek. Since lake chub are tributary spawners (Brown 1971), this species probably utilizes portions of the creek during the spring.

On 16 May 1985, an electrofishing survey of Yellowstone Lake tributaries revealed the presence of an introduced population of brook trout (Salvelinus fontinalis) in Arnica Creek. Subsequent investigation indicated that the nonnative brook trout could not have entered Arnica Creek by natural means; they were apparently introduced by humans. Although nonnative salmonids were historically stocked in the Yellowstone Lake drainage (Jones et al. 1980; Varley 1981), the brook trout in Arnica Creek represented the first established nonnative salmonid population with direct access to Yellowstone Lake and the upper Yellowstone River drainage.

Electrofishing surveys conducted on 40 other tributaries to Yellowstone Lake (Jones et al. 1986; Yellowstone Tributaries, this report), including all spawning

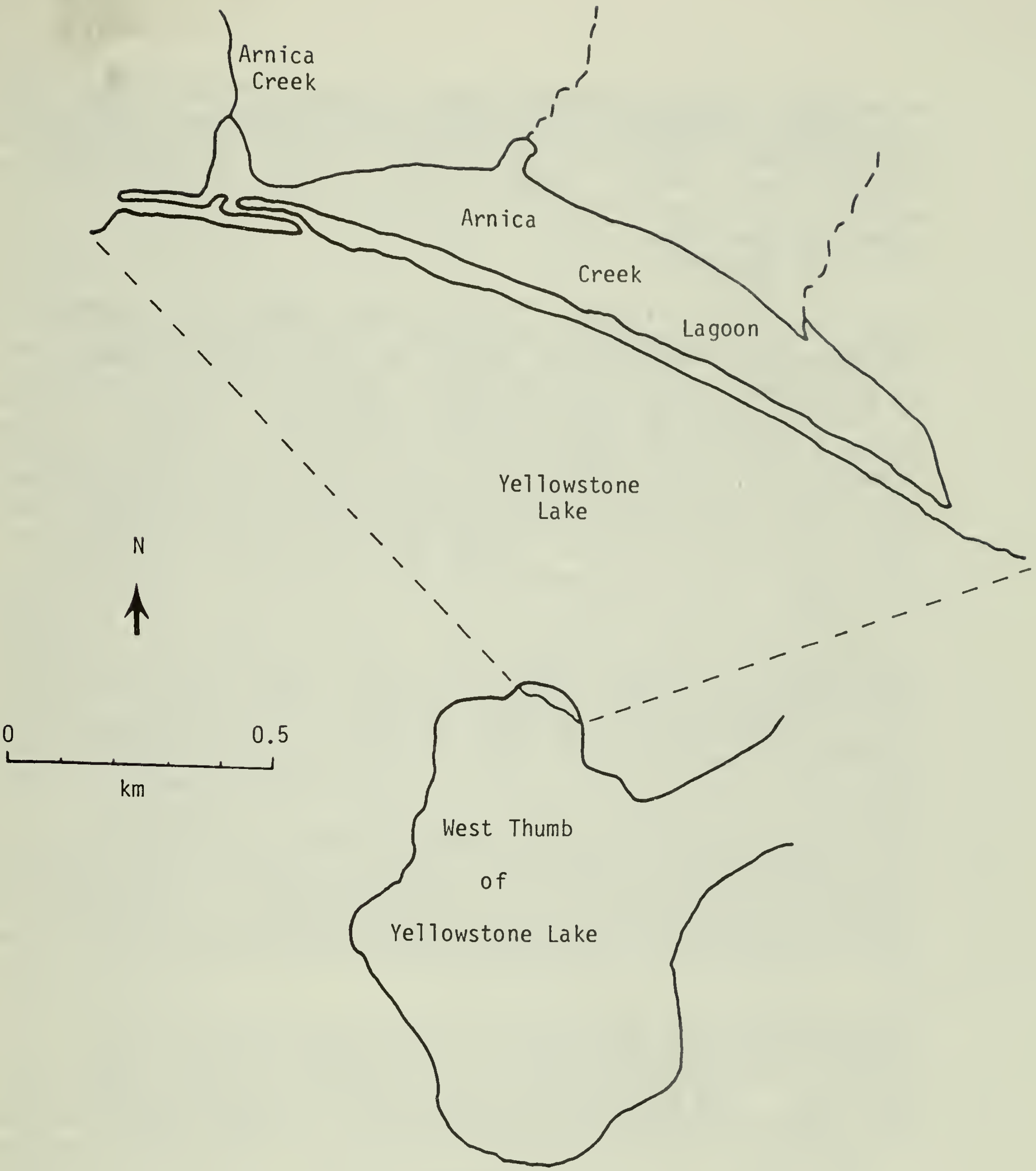

Figure 7. Arnica Creek and Arnica Creek Lagoon in relation to West Thumb of Yellowstone Lake.

streams in the West Thumb region, indicated that brook trout were limited to the Arnica Creek drainage. Within Arnica Creek, most brook trout were located in sections above the main road. Brook trout collected during these surveys varied from age I+ to age III+; however, it appeared that most age III+ brook trout would spawn in the fall of 1985.

Since brook trout posed a significant threat to a unique natural and recreational resource, it was necessary to eliminate all fish in the Arnica Creek drainage (Jones et al. 1986). Expansion of brook trout into other parts of the Yellowstone Lake drainage would have greatly reduced chances of their eventual removal. Initial response included construction of a dike at the mouth of the lagoon to prevent movement of brook trout into the lake. On 27-28 August 1985, a renovation project was initiated on the entire Arnica Creek drainage, including the lagoon, using antimycin, a fish toxicant (Jones et al. 1986).

Expanded estimates (Jones et al. 1986) indicated approximately 12,500 cutthroat trout, 4,000 brook trout, 850 redside shiners, and 800 longnose suckers were removed from the Arnica Creek drainage. An additional 4,000 fish, including longnose suckers, redside shiners, lake chub, longnose dace, and cutthroat trout were killed in the lagoon; brook trout were not recovered from the lagoon. Although some problems occurred with the drip stations and insufficient stream flow, the project appeared successful in Arnica Creek. A second application of toxin to the lagoon appeared to improve initial results, and this portion of the project was also considered to be successful.

Despite encouraging results in 1985, the project was scheduled to be repeated in 1986 in order to insure complete removal of brook trout from the Arnica Creek drainage. The primary objective of this report is to describe the 1986 renovation project on Arnica Creek.

Methods

Arnica Creek

In preparation for the second year of the renovation project, a comprehensive survey of Arnica Creek was initiated on 22 July 1986. Fish distribution within the drainage was determined. Captured brook trout were measured to the nearest 1 mm total length; sex and stage of maturity were noted. Linear distance of the entire drainage was measured. Stream discharge was estimated using the mid-section method (Buchanan and Somers 1969) and, the dye flow method (Hamilton and Bergersen 1984), and fluoroscein dye was utilized throughout the drainage to evaluate flow times between points. Water temperature was measured periodically.

Antimycin was the selected toxin again in 1986. Given the observed range in temperatures (9-14 C) during July and August 1986, Rosenlund (personal communication) recommended a concentration of antimycin of 8 µg/l for the renovation project. He found this concentration was effective for brook trout in streams in Rocky Mountain National Park. Aquabiotics Corporation (undated), the manufacturers of antimycin, recommended 7.5 µg/l of antimycin for waters with a pH < 8.5 and water temperatures < 15.5 C. Since the difference in cost for the additional toxin was minimal, a final target concentration of 8 µg/l was chosen.

By mid-August, some portions of the Arnica Creek drainage had become dry and were no longer connected to the mainstem. For example, portions of tributary stream 118306 still held water, but the lower section was dry. Fish were never collected in the upper portions of the stream, and it was not treated. Final estimates for toxin were based upon approximately 25 km in the Arnica Creek drainage (Figure 8).

A total of 28 drip stations were placed within the drainage (Figure 8). Stations were positioned at the upstream end of major tributaries. Fluorocein dye tests provided information concerning toxin dispersal in the mainstem, and mainstem drip station sites were selected based on the distance traveled by the toxin during a 2-hour period.

Drip stations were constructed from animal "waterers" available at pet stores and farm supply outlets. A small hole was drilled in the pan portion of the waterer, and flow rate was estimated by measuring the volume discharged in a given time period. Since head pressure is almost constant on these waterers, there was virtually no change in delivery rate. Necessary toxin was calculated according to delivery rate, streamflow, and target concentration.

In many areas, streamflow was insufficient to provide adequate distribution of toxin, and backpack sprayers were used to apply antimycin. Three types of sprayers were used in 1986, including fire pumps (both galvanized steel and collapsible bag) and knapsack sprayers. Concentrated antimycin was diluted to a 0.05% solution

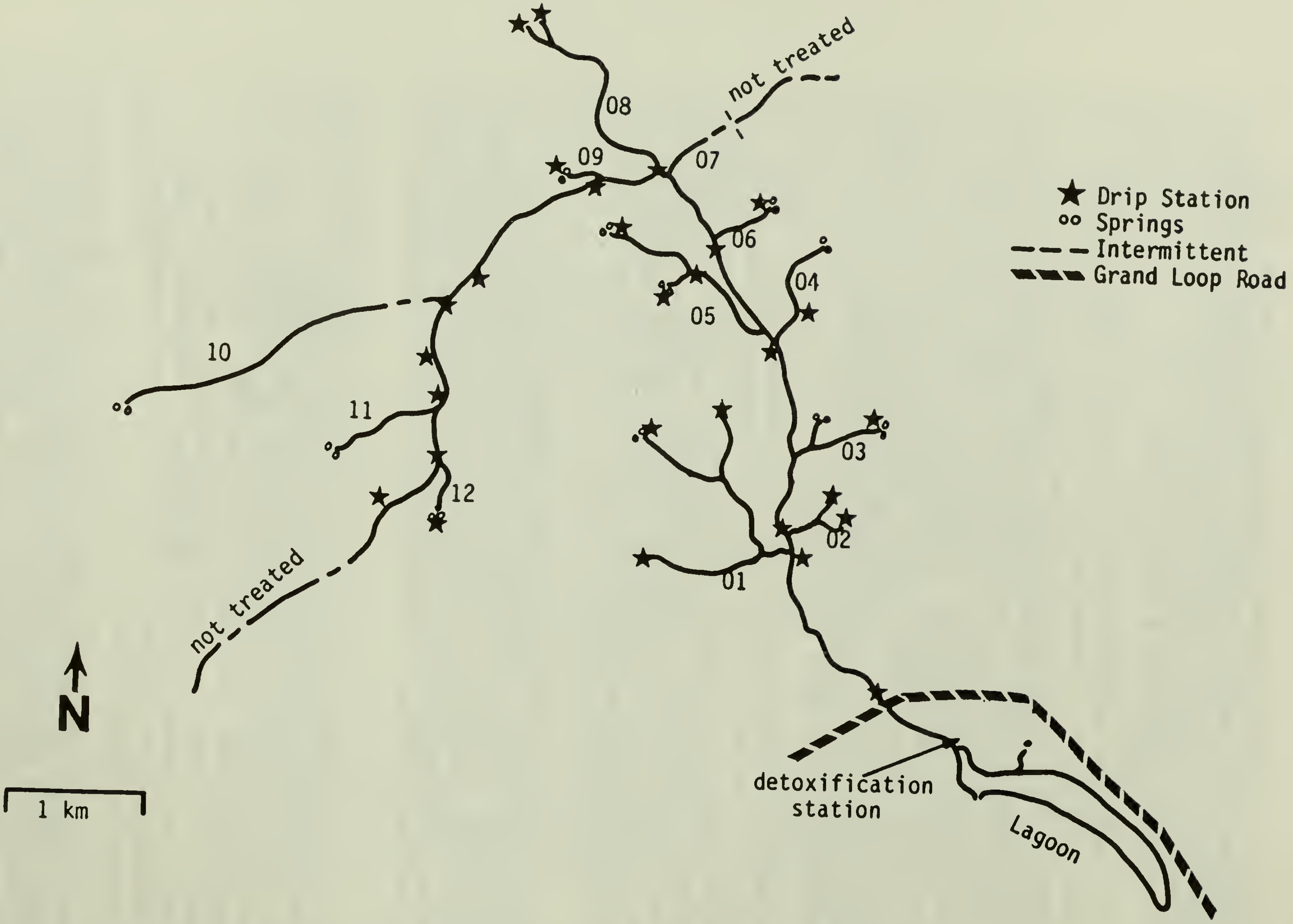

Figure 8 . Antimycin drip stations, Arnica Creek (11830), 1986.

for use in the sprayers; each sprayer contained enough toxin to treat approximately 3,000 m^3 at 8 µg/ml.

Drip stations were started at 0800 hours on 26 August and remained in operation for 10 hours. Most of the observed dead fish were young-of-the-year cutthroat trout; however, no effort was made to collect dead fish, regardless of species.

A detoxification station was situated approximately 100 m upstream from the Arnica Lagoon. A target concentration of 1 mg/ml potassium permanganate (Aquabiotics Corporation undated) was required to detoxify Arnica Creek. The drip station was constructed using a 114 l garbage can; a spigot was attached near the bottom. The system was calibrated to deliver at a rate of 38 l/hr, but changes in head pressure necessitated frequent adjustments to maintain a constant flow.

Arnica Creek Lagoon

High lake levels prevented isolation of Arnica Lagoon from Yellowstone Lake in 1986. During the week of 18 August, the lagoon was sampled by electrofishing from a boat with boom-mounted dropper electrodes (Novotny and Preigel 1974). Pulsed direct current (80 pulses/s) was utilized with a voltage between 100-300 volts. Because none of the fish captured were brook trout, the lagoon was not treated with antimycin in 1986.

Results

The renovation project appeared to be completely successful in 1986. All drip stations worked almost flawlessly. Stations required occasional monitoring to prevent plugging by debris, but if the drain hole was clogged, debris removal took only seconds.

Spraying was extremely effective for areas of low flow. The knapsack sprayers were much more efficient than the fire pumps, and the sprayers seldom leaked, a major probem with the collapsible pumps.

A total of 25 brook trout (mean length 160 mm) were found during pre-treatment reconnaissance surveys; 72% of these trout displayed sufficient gonadal development to spawn in the fall of 1986. During the renovation project, approximately 40 brook trout were observed either dead or in a moribund state. Although none of these trout were collected, sizes appeared to be similar to those from the previous surveys. Brook trout distribution appeared to be confined to an area of the mainstem between tributaries 118303 and 118306 and in the vicinity of the confluence of tributaries 118307 and 118308.

Discussion

The total of approximately 65 brook trout removed from the Arnica Creek drainage in 1986 suggests that the initial project (1985) was very successful. Given the experience gained in 1985, the current project had a high probability of total removal of brook trout from the drainage. Monitoring of fish populations will continue; however, it appears that if brook trout are still found in the drainage, a limited project, aimed specifically at problem sections, would be feasible in the future.

Although the vast majority of the trout killed in 1986 were young-of-the-year cutthroat trout, it appeared that cutthroat trout numbers had declined from pre-treatment surveys. Increased stream discharge caused by heavy rains on 21 August, may have triggered emigration of many fry from Arnica Creek to the lake. The loss of total cutthroat trout production from Arnica Creek in 1985 and a unknown proportion of the production in the current year is an unavoidable consequence of the renovation; however, there are at least five year-classes of cutthroat trout in the lake which will be available to reestablish the spawning migration (Jones et al. 1986).

YELLOWSTONE RIVER (CATCH AND RELEASE AREA)

Approximately 14 km (8.8 mi) of the Yellowstone River between Yellowstone Lake and Upper Falls have been managed under a catch and release regulation since 1973. This area annually supports over 80% of the total angler use on the Yellowstone River (114 km or 71 mi in the park) and is the second most popular park fishery. Although there may be some interaction with cutthroat trout (Salmo clarki) from Yellowstone Lake, this area is treated as a discrete fishery.

Fishery research on the Yellowstone River between the lake and the falls dates back to 1950 (Moore et al. 1952). Since that time, various studies have been conducted to monitor angler impact on this important cutthroat trout fishery. Research since 1973 has been concentrated on the evaluation of the catch and release regulation. In 1986, studies included a voluntary creel survey utilizing the VAR system (Jones et al. 1977) and continued sampling of spawning trout at LeHardy Rapids.

ANGLER USE

In 1986, angler use on the catch and release segment of the Yellowstone River (43,890 angler days) increased 20% from 1985. An estimated 17,600 anglers spent 119,700 hours and captured 119,700 cutthroat trout. Approximately 50 of these trout were illegally creeled. Landing rate (1.00 trout/hour) rose to the highest level since 1983 (Table 15).

When the upper and lower portions of the catch and release area were examined separately, the upper section (9.8 km) sustained 92% of the angler use for the entire area (40,300 angler days or 4,100 angler days/km). A total of 15,700 anglers captured 114,100 trout while expending 111,600 hours of effort. Landing rate was 1.02 trout/hour.

The number of angler days in the lower section (3,560 angler days or 840 angler days/km) increased almost 36% from 1985. Approximately 1,950 anglers expended 8,100 angler hours. Although effort is much lower in this section, landing rate was only 0.68 trout/hour. Expanded results indicate that of 5,400 landed trout, none were illegally creeled.

Average size of landed cutthroat trout for the entire catch and release area was 394 mm (15.5 in). Trout from the upper portion were significantly larger than those in the lower section (402 and 362 mm, respectively).

Table 15. Creel survey summary, Yellowstone River between Fishing Bridge and Chittenden Bridge, 1951-55, 1967, 1976, 1970, 1972, and 1973-86[a].

Regulation		Angler Days	Mean Length Angler Day	Angler Hours	Landing Rate	Total Trout Landed	Creel Rate	Total Trout Creeled	Angler Days Per mile[b]	Angler Days Per Acre[b]	Angler Hours Per Acre[b]	Mean Angler Expertise[c]	Percent Trout Landed And Released[d]	Average Length Trout Landed (inches)
4.2 Fish creel limit[e] No size limit Bait fishing permitted	1951-1955 Average	45,430	1.97	89,500	f)	f)	0.41	36,700	2,800	99	195	-	f)	f)
3 Fish creel limit No size limit Bait fishing permitted	1967-1968 Average	44,300	2.00	88,625	f)	f)	0.43	38,100	4,600	167	334	-	f)	13.5[g]
3 Fish creel limit 14" Minimum size limit Bait fishing prohibited	1970-1972 Average	45,120	1.87	84,700	0.74	62,500	0.18	14,825	4,700	170	318	-	76.2	14.7[g]
Catch and release	1973	25,000	2.35	58,750	1.74	102,200	0.01	590	2,900	106	250	-	99.4	14.3
Lures and flies only	1974	23,900	2.31	55,700	2.25	124,200	0.01	550	2,700	102	235	-	99.9	14.4
Bait fishing prohibited	1975	27,900	2.48	69,200	2.04	141,100	0.01	690	3,200	119	295	-	99.5	14.5
	1976	30,900	2.45	75,700	1.43	108,200	0.01	980	3,600	132	322	2.00	99.8	14.7
	1977[h]	26,900	2.44	65,600	1.43	93,900	0.02	1,300	3,100	114	279	1.98	99.6	14.7
	1978	26,300	2.50	65,700	1.23	80,800	0.02	1,100	3,000	112	280	1.99	99.6	15.1
	1979	28,900	2.60	75,300	1.10	82,800	0.02	1,500	3,300	123	320	2.02	99.3	15.3
	1980	34,900	2.44	85,100	1.06	88,700	0.02	2,000	4,000	148	362	2.04	99.0	15.3
	1981	48,800	2.60	126,800	1.00	127,100	0.01	1,800	5,600	208	540	2.01	99.8	15.4
	1982	35,200	2.46	86,600	1.10	95,400	0.02	1,400	4,000	150	369	2.00	99.6	15.6
	1983	39,300	2.61	102,400	1.06	109,000	0.01	1,400	4,500	167	436	1.98	99.9	15.6
	1984	44,500	2.56	114,000	0.96	109,000	0.02	2,500	5,100	189	485	2.00	99.0	15.8
	1985	36,600	2.72	99,400	0.91	90,500	0.02	1,400	4,200	156	423	2.02	99.7	15.8
	1986	43,900	2.73	119,700	1.00	119,700	0.01	1,500	5,000	187	509	2.05	100.0	15.5

a) Statistics for 1951 through 1972 have been converted from summer to season-long estimates.
b) Yellowstone River between Fishing Bridge and Chittenden Bridge is 16 miles long and averages 458 acres. Area open to fishing was 9.7 miles and 265 acres between 1965 and 1972. Beginning in 1973, the area open was 8.7 miles and 235 acres.
c) Based on formula: 1.0 = inexperienced, 2.0 = experienced, 3.0 = expert.
d) Based on reported data from Volunteer Angler Report.
e) 3 years of 5 fish creel limit plus 2 years of 3 fish creel limit.
f) Not measured.
g) Based on data from creeled trout.
h) Revised upward 6% from that reported (Jones et al. 1978).

Mean length of creeled trout for the entire catch and release area was 322 mm.

Approximately 85% of the anglers were satisfied by their overall experience, 79% were satisfied with numbers landed, and 87% were satisfied with size of fish landed. Levels of satisfaction increased from 1985, and estimates remain well above the park mean (Table 5). The proportion of single day anglers landing one or more trout was 72%; average expertise remained high at 2.05.

LEHARDY RAPIDS

In 1973, a catch and release regulation was placed on a portion of the Yellowstone River from 1.6 km below the Yellowstone Lake outlet downstream to the Sulphur Caldron (Dean et al. 1974). The Yellowstone River cutthroat trout spawning migration has been monitored at LeHardy Rapids annually since 1974 to evaluate the effects of this regulation on the population structure. This sampling program provides an alternate means of monitoring the population independent of the VAR system.

Results and Discussion

Lengths, weights, and age data were obtained from 596 adult cutthroat trout during weekly sampling between 4 June and 17 July. Average length of adult trout was 396 mm. Mean length of males and females was 405 and 388 mm, respectively. Mean weight (565 g) and condition factor (0.84) for adult males were the highest values recorded since sampling began in 1974 (Table 16). Mean weight for adult females was 503 g and average condition factor was 0.85. Average weight and condition factor for all adults were 532 g and 0.85, respectively.

The male:female ratio was 0.88:1. Since 1974, the male:female sex ratio of sampled trout has ranged from 0.72:1 to 2.03:1.

Average age of an expanded sample of 582 trout (6.1 years) was the oldest recorded age since the program began in 1974. Average age of males and females was 6.8 and 5.9 years, respectively.

The general trend from 1974-86 has been increased length, weight, and age of all adults (Figures 9, 10, and 11). Data collected since 1974 suggests that by substantially reducing angling mortality, the catch and release regulation has had a positive impact on cutthroat trout migrating through this portion of the Yellowstone River.

Table 16. Total number and average length, weight and condition factor of cutthroat trout for each year sampled at LeHardy Rapids, Yellowstone River, 1974-1986.

	Adult Males				Adult Females				All Adults				Immatures and Subadults			
Year	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor	Number captured	Average length (mm)	Average weight (g)	Average K factor
1974[a]	177	375	394	0.75	244	352	339	0.78	453	362	363	0.76	43	177	60	0.84
1975	338	385	451	0.78	426	359	363	0.78	775	370	401	0.78	40	205	118	1.04
1976[a]	531	384	431	0.75	423	362	360	0.75	964	375	399	0.75	29	173	71	1.04
1977[a]	133	382	429	0.77	111	362	370	0.78	245	373	402	0.77	2	250	139	0.87
1978	399	386	458	0.78	358	364	413	0.85	759	376	437	0.81	68	169	62	0.96
1979	334	394	514	0.83	237	371	431	0.84	571	385	480	0.83	5	225	122	0.91
1980	293	391	488	0.81	190	372	418	0.80	483	384	460	0.81	2	247	184	0.94
1981	383	394	496	0.80	188	373	440	0.84	571	387	478	0.82	7	308	286	0.89
1982	327	401	517	0.80	367	380	474	0.86	694	389	494	0.83	26	281	218	0.90
1983	338	402	546	0.83	232	380	276	0.86	570	394	517	0.84	1	225	100	0.88
1984[b]	321	408	539	0.79	199	386	477	0.82	526	399	515	0.80	0	---	---	----
1985[b]	269	408	554	0.82	161	391	513	0.85	431	402	539	0.83	1	199	70	0.89
1986[b]	279	405	565	0.84	316	388	503	0.85	596	396	532	0.85	7	230	122	0.94

a) Due to erroneous measurements, fish were deleted from average weight and K factor calculations only, as follows: 6 males and 2 females from 1974, 1 male and 2 females from 1976, and 1 male and 1 female from 1977.

b) Six adults in 1984, one adult in 1985, and one adult in 1986 were not identified to sex.

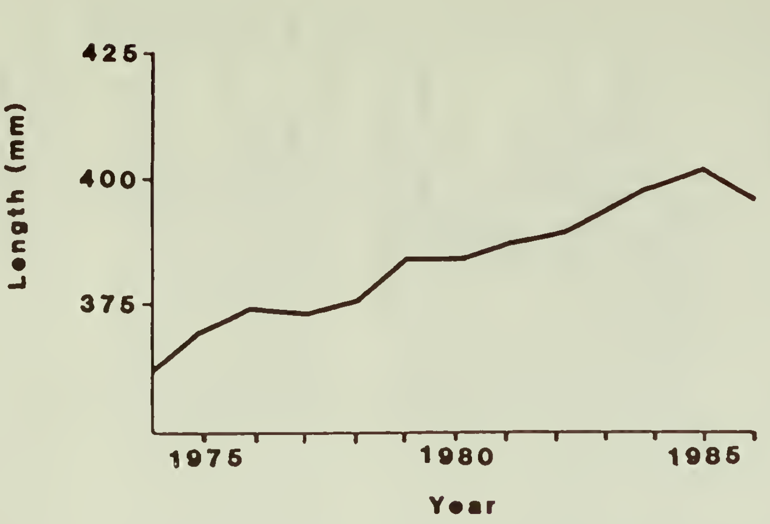

Figure 9. Average length for the entire season for all adults, LeHardy Rapids, 1974-86.

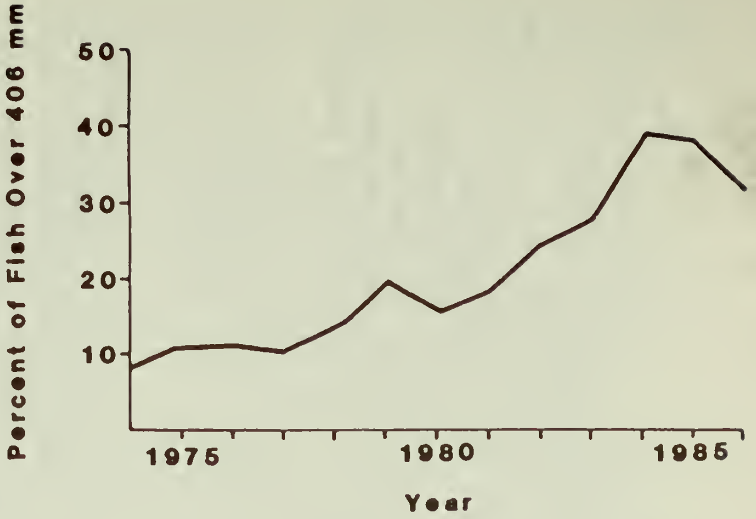

Figure 10 . Percentage of adult trout greater than 406 mm captured at LeHardy Rapids, 1974-86.

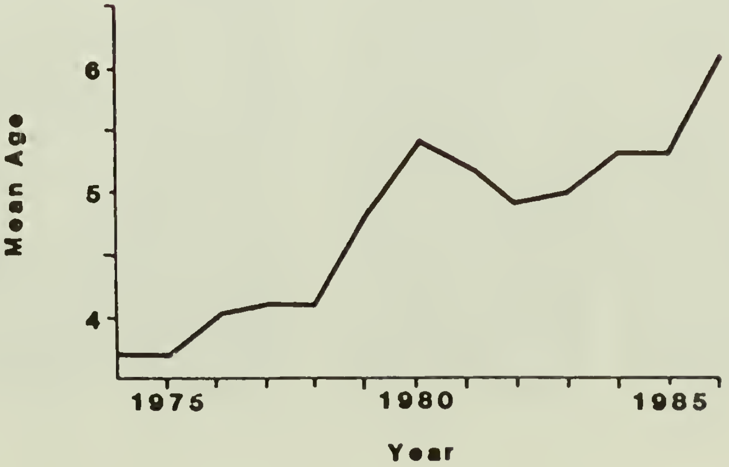

Figure 11. Average age of all adult trout captured at LeHardy Rapids, 1974-86.

CONCLUSION

Angler use and effort have increased steadily since the catch and release regulation was implemented in 1973. Despite a precipitous decline in use after this regulation was initiated, current levels remain high (Table 15). These figures equated to 3,100 angler days/km (5,000 angler days/mi), or 462 angler days/ha (187 angler days/acre) in 1986. According to these data, the catch and release portion of the Yellowstone River sustains the highest level of use in the park and is probably one of the most intensively fished wild trout fisheries in North America. Angler effort per unit area on this section of the river (1,255 angler hours/ha or 509 angler hours/acre) remains extremely high (Table 15).

Increasing use and effort have affected the landing rate in this section of the Yellowstone River. As effort declined after implementation of catch and release, landing rate more than doubled and rose to a high of 2.25 trout/hour in 1974 (Table 17). As effort increased, landing rates gradually declined. Despite record levels of effort, however, landing rate remains over 0.90 trout/hour.

Regardless of increases in effort and concomitant decreases in landing rate, size structure of the population has been moving toward historic proportions. Length-frequency analysis of cutthroat trout captured in the spawning run at LeHardy Rapids reveals a definite shift towards larger trout (Figures 9 and 10, Table 16, and Appendix A Table 10). Length frequency and mean length of cutthroat trout landed by anglers also indicates a substantial increase in larger trout since 1973 (Tables 15 and 17). A general rise in average age has accompanied the increase in size at LeHardy Rapids.

Although there is an inverse relationship between effort and landing rate, changes in population structure may also have influenced landing rate. As biomass shifts toward older and larger trout, the total number of trout will probably decrease (Nikolskii 1969). The interaction of these two factors (increases in effort and shifts in structure) may continue to lower landing rates in the future.

Hooking mortality and recatchability are critical to the success of the catch and release regulation. Schill et al. (1986) reported hooking mortality of 0.3% on a per capture basis, or 3% of the total population for a portion of the upper catch and release section in 1981.

The recatchability of the cutthroat trout is evidenced in these estimates. Comparison of total landings for the 4.5 km study area in the upper portion of the catch and release section (72,700 cutthroat trout) and population estimates for the same segment (7,500 trout/km) suggested that trout were captured an average of 9.7 times during the 45-day study period (Schill et al. 1986). This figure emphasizes the value of the catch and release regulation and illustrates how such a regulation can support high levels of effort on a cutthroat trout fishery.

Although it is possible that effort may rise to a point that the catch and release regulation can no longer maintain angling excellence, it is evident that this regulation currently supports record levels of use while still providing the important elements of quality. Population estimates and creel data reveal the necessity for low mortality and high recatchability to accomplish these management goals. It is evident that both factors are closely related to the species and the habitat involved. The high recatchability of cutthroat trout and excellent habitat conditions in this portion of the Yellowstone River undoubtedly contribute to the continued success of the catch and release regulation.

Table 17. Percentage of trout in various length categories, catch and release section, Yellowstone River, 1973-86.

Year	305 mm	356 mm	406 mm	457 mm	508 mm
1973	86.3	62.5	17.3	3.1	0.7
1974	89.5	63.3	26.6	6.6	1.2
1975	92.7	60.4	15.4	2.6	0.3
1976	90.0	67.7	24.3	4.4	0.7
1977	89.2	68.7	26.2	5.3	0.9
1978	91.1	71.6	33.2	9.0	1.8
1979	92.5	77.5	35.9	8.7	1.0
1980	93.8	77.8	37.6	9.2	1.2
1981	95.4	82.6	35.8	7.6	1.1
1982	96.4	82.3	40.7	8.6	1.5
1983	96.7	85.9	39.9	10.7	2.3
1984	95.9	84.3	46.6	12.3	1.9
1985	95.7	84.5	47.8	12.7	2.6
1986	92.7	80.2	43.6	12.3	1.9

LAKE SURVEY PROGRAM

INTRODUCTION

Since 1963, data describing physical, chemical, and biological parameters of 112 park lakes have been collected in conjunction with the lake survey program. The objective of this program is the fundamental inventory of lacustrine systems which provides baseline data necessary to assess changes through time. Analysis of angler impact is an integral part of this program and has been utilized to monitor the effects of various angling regulations. In 1986, an aquatic survey was conducted on one lake. Although sampling techniques have varied during the past 23 years, data are reasonably comparable.

METHODS

With few exceptions, current methods are those described by Dean and Mills (1970). Since 1974, one water sample from each lake has been analyzed by a commerical laboratory. In order to enhance comparability, additional samples have been collected for many of the lakes surveyed prior to 1974.

Plankton samples have been collected with a Wisconsin plankton net; a single 9.1 m oblique tow, has been made for each lake survey since 1973. In lakes where maximum depth was <9.1 m, the number of tows was increased at a shallower depth so that the total volume sampled was equivalent. From 1973 through 1980, plankton were enumerated by a method modified from McNabb (1960). Since 1981, zooplankton and phytoplankton samples have been quantified using methods described by Wetzel and Likens (1979).

Both largemesh and smallmesh experimental gillnets have been utilized to sample aquatic vertebrate populations since 1971. Largemesh nets are 38.1 m long with 7.6 m graduated mesh panels of 19, 25, 32, 38, and 51 mm bar mesh. Smallmesh nets are 30.5 m long with four 7.6 m panels of 10, 13, 16, and 19 mm bar mesh. Both types of nets are approximately 1.8 m deep and constructed of monofilament materials.

RIDDLE LAKE

Riddle Lake is a moderate size backcountry lake with a surface area of 110.9 ha. A well marked trail (3.5 km long) provides easy access from the trailhead located approximately 4 km south of Grant Village on the South Entrance Road. The area is extremely popular for day use, but overnight camping was prohibited beginning in 1985.

Cutthroat trout (Salmo clarki) are native to Riddle Lake and were the only species present historically. Currently both longnose suckers (Catostomus catostomus) and redside shiners (Richardsonius balteatus) also inhabit the lake. It is assumed that the cutthroat trout and the nonnative species originally gained entry from Yellowstone Lake via Solution Creek.

Lake surveys conducted in 1970 and 1971 described physical and chemical properties of the lake and presented data concerning the fish population under the 356 mm minimum size (2 fish creel) regulation in effect at that time (Dean 1972). The regulation changed to a 356 mm maximum size limit in 1974, but creel limit remained unaltered. In that year, the lake was resurveyed in order to determine the method of recruitment for the cutthroat trout population and to evaluate angler response to the new regulation (Dean et al. 1975). The size limit was changed again in 1975 to coincide with the 330 mm maximum size regulation on Yellowstone Lake. A fourth survey conducted in 1981 indicated that the 330 mm maximum size limit had failed to provide adequate protection for the cutthroat trout in Riddle Lake (Jones et al. 1982). Since the recommended catch and release regulation could not be initiated, the lake was closed to all sport angling in 1982.

Results of a survey conducted in 1983 indicated that the cutthroat trout population had continued to decline (Jones et al. 1984). Lack of Volunteer Angler Report (VAR) data due to the angling closure limited the means of evaluating changes in the Riddle Lake cutthroat trout population. An increase in sampling intensity was recommended in order to improve documentation and interpretation of current trends. A similar recommendation was made after a subsequent survey was conducted in 1984 (Jones et al. 1985). Some increase in cutthroat trout density was noted, but restoration of this species in Riddle Lake was not proceeding rapidly. Continued protection from sport angling was suggested.

In order to continue monitoring activities on the cutthroat trout population, an abbreviated lake survey was conducted 3-4 September 1986.

Physical

Jones et al. (1982) provided a detailed physical description of Riddle Lake. In 1986, water temperature varied from 15.3 C at the surface to 13 C at the bottom (7 m). Secchi disc visibility was 3.4 m in the tea-brown water. The 1986 reading is unchanged from 1983 and 1984 (Jones et al. 1985); however, recent values are somewhat greater than that reported in 1981 (3.0 m) (Jones et al. 1982).

Chemical

On the basis of the water sample collected at 1.8 m below the surface, Riddle Lake (TDS = 10 ppm) was again classified as a dilute lake (TDS < 50 ppm). Predominant ions were calcium and bicarbonate (Table 18). Dominant ions continued to vary in Riddle Lake; such changes have occurred often among samples from dilute park waters. This variability is probably related to the extremely low chemical concentrations in conjunction with differences in physical and biological conditions at the time of sampling. Thus far, Riddle Lake has displayed at least five different ion types (Jones et al. 1982).

Of principal interest, however, is the nutrient paucity of Riddle Lake (Table 18). Most chemical constituents are below the park mean for dilute lakes (n=54). Silica levels were below the level of detection (0.1 ppm). Low levels of essential nutrients may limit fish populations in Riddle Lake.

Aquatic Vertebrates

One smallmesh and two largemesh gillnets captured 22 cutthroat trout, 78 longnose suckers, and 2 redside shiners.

Cutthroat Trout

Average length of the 22 trout was 228 mm. Mean weight was 120 g for 20 of the trout; mean condition factor was 0.81 (Table 19). Male:female ratio was 1.75:1. Of eight females, three were categorized as prespawners (sufficient gonadal development to spawn in 1987).

Back-calculated lengths for 17 trout were 56, 124, 171, 251, and 293 mm for ages I-V, respectively (Table 20). None of the trout displayed a "retarded" scale pattern (Laakso 1955). Mean age was 3.0 years; 48% were age II or less (Table 21).

Table 18. Chemical characteristics of Riddle Lake, Yellowstone National Park, 1963-86.

	07/30/63	07/29/70	08/01/74	08/24/79	10/16/79	09/01/81	09/08/83	08/07/84	09/03/86
Water Temp. °C	-	17.2	19.4	-	7	13.8	15.0	18.3	15.0
Spec. Cond. (µmhos)*	24.0	22	30	-	30	40	25	20.9	210
pH*	6.8	7.0	6.5	-	6.8	6.75	6.75	6.75	6.75
Diss. Oxygen (ppm)	-	6.1	7.0	-	-	5.8	5.8	6.2	6.2
Pheno. Alkalinity	0	0	0	0	0	0	0	0	0
Total Alkalinity	7.2	11	25	27	9.6	12	9	8.1	13.0
Ca Hardness	-	-	10	12	6	12	<2.5	4.99	4.79
Total Hardness	-	-	25	24	8	-	<6.6	<9.11	<8.91
Total Diss. Solids	34.0	-	-	23	20	34	12	13	10.0
Carbonate Alkalinity	0	0	0	0	0	0	0	0	0
Bicarbonate Alkalinity	7.2	11	25	27	9.6	12	9	8.1	13.0
Carbonates	-	-		0	0	0	0	0	0
Bicarbonates	-	-		33	12	14.6	11	9.9	15.9
Hydroxides	-	-		0	0	0	0	0	0
Carbon dioxide	-	3.5		277	80	2.4	7.5	2.63	9.8
Chloride	-			<1.0	<1.0	0.9	0.98	<1.0	<1.0
Sulfate	7.2			1	6	15	11	2.1	3.4
Fluoride	-			0.1	0.04	0.20	0.59	0.041	0.035
Potassium	1.67			-	1.1	0.07	0.64	<1.0	<1.0
Mg Hardness	-			12	2	2	<4.1	<4.12	<4.12
Calcium	3.2			4.8	2.4	4.8	<1.0	2.00	1.92
Magnesium	0.97			2.9	<0.5	0.5	<1.0	<1.00	<1.00
Sodium	1.17			3	2.4	0.6	1.3	1.02	<1.0
Iron				0.15	0.04	0.24	0.26	0.29	0.18
Manganese				<0.05	<0.05	0.05	<0.05	<0.05	<0.05
Copper				<0.1	<0.1	0.03	0.01	<0.01	<0.01
Silica				0.7	0.25	0.1	0.3	<0.1	1.1
Color (PCU)				10	0	30	0	30	25
Turbidity (NTU)				2.1	0.69	0.7	0.25	1.4	0.6
Total Organic Carbon					9.4	8.6	8.1	<1.0	7.1
Total Phosphate					9.4	0.09	0.09		<0.80
Kjeldahl N					1.1	0.84	0.44		
Nitrate N*					0.08	0.02	<0.02		

* Field measurements, all others made by commercial laboratory.

Table 19. Gillnetting results from Yellowstone backcountry lakes surveyed, 1970-86.

Location	Species	Year	Number of Nets[a]		Total Number Captured	Length (mm)			Weight (g)			Mean K Factor
			Largemesh	Smallmesh		mean	n	range	mean	n	range	
Riddle Lake	Cutthroat Trout	1970[b]	3	0	50	298	50	175-415	264	50	56-604	0.86
		1971[b]	3	1	63	308	63	90-455	298	63	6-836	0.91
		1974[c]	3	2	77	261	77	117-420	221	77	12-600	0.89
		1981[d]	2	1	35	189	29	75-282	79	29	6-182	0.90
		1983[e]	2	1	13	250	13	138-332	150	13	112-322	0.83
		1984[f]	2	1	25	217	25	140-326	120	24	21-321	0.85
		1986	2	1	22	228	22	156-337	120	20	37-310	0.81
	Longnose Sucker	1970	3	0	14	238	14	190-250	142	14	76-164	1.04
		1971	3	1	1	270	1	---	220	1	---	1.12
		1974	3	2	87	163	87	112-392	67	87	12-624	0.98
		1981	2	1	140	288	139	105-448	386	66	90-986	1.14
		1983	2	1	69	325	69	214-453	397	69	100-928	1.05
		1984	2	1	127	312	127	174-436	360	103	80-796	1.00
		1986	2	1	78	325	78	105-450	389	42	5-840	0.96

a) Largemesh: monofilament experimental gillnets 38.7 m long x 1.5 m deep with 7.6 panels of 19, 25, 32, 38, and 51 mm bar mesh;
smallmesh: monofilament experimental gillnets 30 m long x 1.8 m deep with 7.6 m panels of 10, 13, 16, and 19 mm bar mesh.
b) Dean 1972.
c) Dean et al. 1975.
d) Jones et al. 1982.
e) Jones et al. 1984.
f) Jones et al. 1985.

Table 20. Back-calculated total length at annulus formation of fish captured in Yellowstone backcountry lakes, 1971-86.

Location	Species	Year	Sample Size	Annulus I	II	III	IV	V
Riddle Lake	Cutthroat Trout	1971a)	19	61	130	221	297	351
		1974b)	41	66	132	183	249	312
		1983c)	13	65	163	235		
		1984c)	21	63	152	236	298	
		1986	17	56	124	171	251	293

a) Dean 1972.
b) Dean et al. 1975.
c) Scales for current report.

Table 21. Age frequency (by percentage) of fish captured in Yellowstone backcountry lakes, 1971-86.

Location	Species	Year	Sample size	Percentages in each age I	II	III	IV	V	Mean age (years)
Riddle Lake	Cutthroat Trout	1971a)	19	5	11	26	53	5	3.4
		1983b)	13	15	23	62			2.5
		1984b)	24	42	25	17	17		2.1
		1986	22	0	48	16	27	9	3.0

a) Dean 1972.
b) Scales reread for current report.

Comparison with prior surveys revealed a 12% decrease in the number of trout captured per net since 1984 (Figure 12). Mean length increased in 1986 (Figure 13); however, only one trout captured in 1986 exceeded 330 mm.

In order to increase comparability of length data, the length-categorization system introduced by Anderson (1976) and modified by Anderson and Weithman (1978) and Gabelhouse (1984) (see Fall Gillnetting section; this report) was applied to the Riddle Lake data. Since the world record cutthroat trout reported by Gabelhouse (1984) was uncharacteristic of that species in Yellowstone National Park, the park record for cutthroat trout, a 660 mm specimen from Heart Lake, was used to determine minimum lengths for stock, quality, and preferred size categories (153 mm, 254 mm, and 330 mm, respectively). The resulting comparisons of PSD and RSD-preferred vary concomitantly with changes in mean length (Figure 14). Present distribution suggests the proportion of larger trout observed in the early 1970's has not been approached in recent years.

Longnose Sucker

Total length of 78 suckers ranged from 105 to 450 mm with a mean of 325 mm (Table 19). Mean weight and condition factor (K) were 389 g and 0.96, respectively.

Despite a substantial increase in the number of suckers captured between 1971 and 1981, the estimates have fluctuated greatly in recent years (Figure 12). Average length has varied significantly among sample years, and there is a definite trend toward larger suckers (Figure 13). The slight decrease in mean length in 1984 was followed by return to the 1983 mean (325 mm) during the current year.

Angler Use

Angler use more than doubled between 1975 and 1981 (Jones et al. 1982); however, angling closure eliminated fishing beginning in 1982. This sudden decrease in angler use at Riddle Lake was evident in the overnight use at the four campsites between 1982 and 1984 (Jones et al. 1985). Riddle Lake remains closed to angling, and overnight use of the area was discontinued in 1985 for bear management purposes.

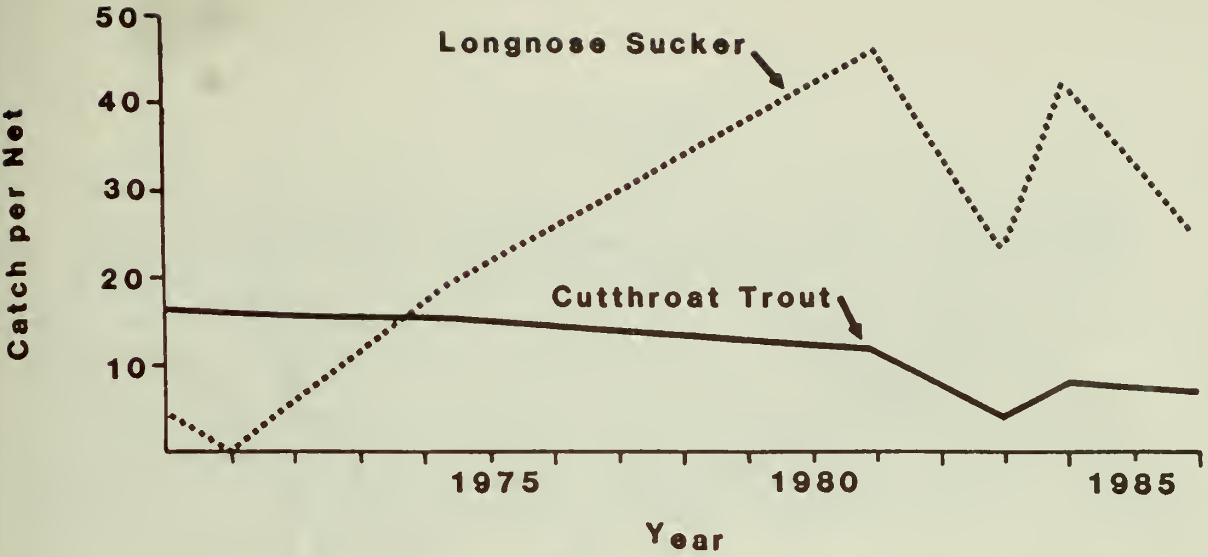

Figure 12. Mean number of cutthroat trout and longnose suckers captured per net in experimental gillnets, Riddle Lake, 1970-86.

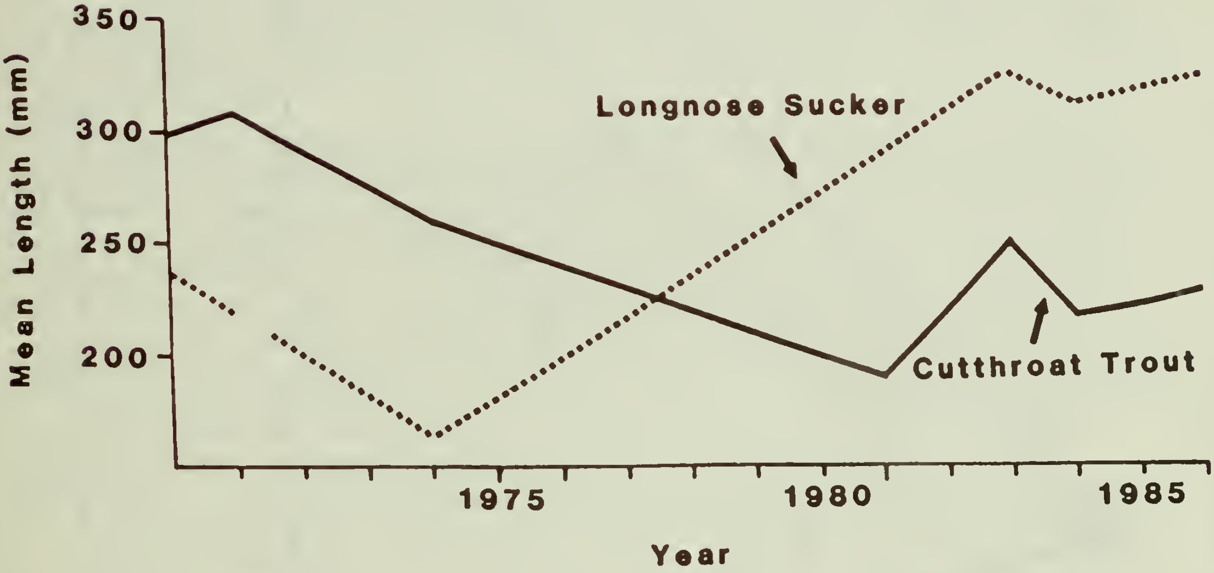

Figure 13. Mean length of cutthroat trout and longnose suckers captured in gillnets, Riddle Lake, 1970-86.

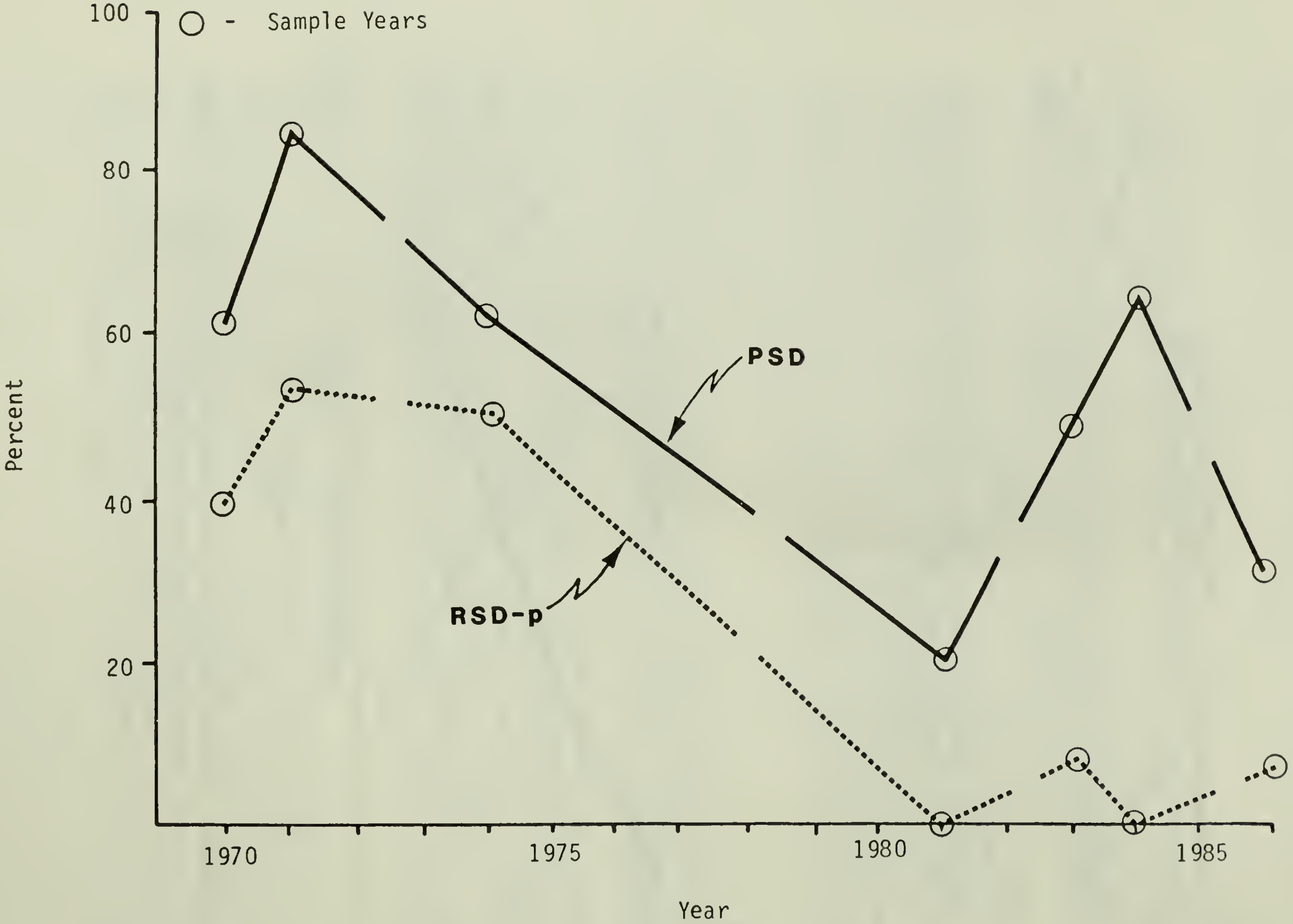

Figure 14. Proportional Stock Density (PSD) and Relative Stock Density-Preferred (RSD-P) for gillnet captured cutthroat trout, Riddle Lake, 1970-86.

Discussion

Current data suggest that densities of cutthroat trout have continued to decrease in Riddle Lake. Mean length of cutthroat trout remains low despite slight increases in 1983 and 1986. Average age increased in 1986, but growth rate has declined slightly. These changes in population structure are apparently associated with declining densities indicated by gillnet catches since the early 1970's. Evaluation of angling closure on Riddle Lake continues to be hampered by the lack of VAR data. Without this angler provided data, it is difficult to substantiate trends suggested by gillnetting results.

Expected increases in cutthroat trout density and improvement in population structure have not been observed since Riddle Lake was closed to angling in 1982. Low numbers of mature females suggest a poor reproductive potential, and observed changes in population structure may be a function of extreme variation in reproductive success. Reexamination of available spawning habitat should be incorporated in future surveys of Riddle Lake in order to evaluate this important component of the cutthroat trout population in Riddle Lake.

Longnose suckers have increased in Riddle Lake while trout densities declined; however, a causal relationship has not been established. Studies in Yellowstone Lake have failed to substantiate competition between the two species, but it is possible that the habitat of Riddle Lake might be more conducive to competition; small size, shallow average depth, and low productivity combine to limit fish populations in the lake. On the other hand, the longnose sucker has been aged up to 28 years old in Yellowstone Lake (Jones et al. 1977), and therefore, expansion of the population would be slow (Nikolskii 1969). In Yellowstone Lake, significant increases were first noted 10 to 20 years after routine eradication of sucker spawners was curtailed. The current expansion of suckers in Riddle Lake may be associated with increases in Yellowstone Lake and Solution Creek and thus, coincidental to declines in trout numbers.

Increases in sucker mean length may be a manifestation of the "pioneering" effect as the longnose sucker population begins to expand in Riddle Lake. A similar increase in size might occur if sporadic reproductive success produces greatly fluctuating year-class strength; however, an increase in the proportion of smaller suckers suggests that this species may be reproducing successfully in Riddle Lake.

Attempts to understand rather distinct changes which have apparently occurred since the early 1970's should not ignore an important confounding factor; the observed changes have coincided with a change in the number and type of gillnets used for sampling. Those years with the largest mean length and number captured also had a greater proportion of largemesh nets. Since largemesh nets often catch larger trout, a reduction in the number of largemesh nets may confound comparisons. Considering the great variability encountered with gillnets (Lagler 1978), changes in the sample sites may also influence results. Since 1981, sample sites have remained unchanged; however, the previous netting locations are unknown.

Original observations of a declining cutthroat trout fishery in Riddle Lake were substantiated by VAR data, but without this important source of information, it is difficult to interpret current findings. Apparent declines in the cutthroat trout population do not appear to have abated. Allowing catch and release angling in Riddle Lake would provide additional data and subsequently improve the monitoring capabilities for this puzzling fishery. Increased sampling, perhaps utilizing electrofishing (see Sylvan Lake, Jones et al. 1986), is also recommended to provide the information necessary to more thoroughly evaluate the Riddle Lake fishery. Although observed changes may have a biological basis, it is obvious that such conclusions cannot be accepted at this time.

STREAM SURVEY PROGRAM

Introduction

Scientific researchers and fishery managers have long been interested in the aquatic resources of Yellowstone National Park (YNP). Jordan (1891) conducted the first comprehensive survey of physical features of lakes and streams, distribution of native fishes, and waters barren of fish, and Evermann (1892) evaluated the success of nonnative fish plants that occurred between 1889 and 1890. Over the next 70 years, independent researchers, the National Park Service (NPS), and the U.S. Bureau of Sport Fisheries and Wildlife (BSFW) examined many aspects of aquatic ecology and fishery management in YNP. Not until 1965, however, did the NPS formally request that the BSFW systematically inventory the aquatic resources of YNP (Sharpe and Arnold 1966). Inventories were to include a basic assessment of numbers and types of waters, collections of physical, chemical, and biological data, and analyses of angler impacts on fish populations (Jones et al. 1983).

Since 1965, the BSFW and its successor, the U.S. Fish and Wildlife Service (USFWS), have actively pursued a stream survey program in YNP. Although goals, objectives, and methods of the program have varied over the years, the data have been used to address the broad issues of stream inventory and fishery evaluation. Stream inventory involves developing a qualitative and/or quantitative description of a stream based on measurements of physical, chemical, and biological parameters. Inventories are useful in grouping waters with similar characteristics, ultimately leading to greater understanding of natural processes regulating stream ecosystems (Olson et al. 1981). Fishery evaluation, of which stream inventory is a part, involves determining the biological status of a stream based on the fish species present and their relative productivity (Olson et al. 1981). Applications of fishery evaluation include assessing impacts of human activity (e.g., angler harvest or land use), and developing fishery management plans.

In 1986, stream survey efforts were concentrated in the Lamar River drainage. Due to logistic constraints, complete surveys of the major streams in this river system have encompassed two field seasons. Results from 1985 and 1986 have been combined in this report.

Methods

Three types of stream surveys are conducted to obtain information to describe and evaluate stream fisheries. Cursory-level surveys (Table 22) provide a general physical, chemical, and biological stream description. Stream order, watershed size, elevation, stream length, and gradient are determined from U.S. Geological Survey topographic maps (scale 1:62,500); remaining parameters are measured at the stream mouth. Intermittent and ephemeral streams which are dry at the time of sampling, but may contribute significant amounts of sediment to a stream system when flowing, are included in cursory-level surveys. Data compiled during cursory-level surveys are often used to prioritize which streams should be more intensively sampled.

Reconnaissance-level surveys (Table 22) give a detailed stream description. Streams are subdivided into reaches which are relatively uniform with respect to gradient, discharge, and/or riparian vegetation. Within each reach, 29 stream features are measured, and cursory-level surveys are conducted on all tributaries. Measurements of stream features have generally followed procedures outlined by Platts et al. (1983) (Appendix B).

Ecological performance-level surveys (Table 22) provide a means to evaluate fisheries. Estimates of the numbers, biomass, and/or population structure are made in conjunction with measurements of stream habitat features. Angler use and effort are estimated through returns from the Volunteer Angler Report system. In this way, the biotic potential of the fish population may be related to stream habitat conditions, and the influence of angling on fish populations may be assessed.

LAMAR RIVER DRAINAGE

The Lamar River is the largest tributary of the Yellowstone River in Yellowstone National Park (YNP). Located in the northeastern portion of the park, the 129,500 hectare Lamar River watershed represents nearly 15% of the entire park area and contains approximately 20% of the total stream length in YNP. At the confluence with the Yellowstone River, the Lamar River is a fifth order stream.

Studies of the Lamar River have been limited to the area from Cold Creek downstream to the confluence with the Yellowstone River. Arnold and Sharpe (1967) utilized

Table 22. Type of information collected during cursory, reconnaissance, and ecological performance surveys in Yellowstone National Park, 1986.

Cursory	Reconnaissance (by reach)	Ecological Performance
Stream Order	Stream Order	Stream Order
Watershed Size	Elevation	Elevation
Elevation	Beaver Activity	Beaver Activity
Length	Wildlife Observations	Wildlife Observations
Gradient	Weather	Weather
Water Flow	Presence or Absence of Fish	Presence or Absence of Fish
Water Temperature	Stream Bottom Contour	Stream Bottom Contour
pH	Water Flow	Water Flow
Conductivity	Water Column Features:	Water Column Features:
Macroinvertebrate Species Composition	Channel Width	Channel Width
Presence or Absence of Fish	Stream Width	Stream Width
	Water Depth	Water Depth
	Riffle Width	Riffle Width
	Pool Width	Pool Width
	Pool Quality	Pool Quality
	Solar Incidence	Solar Incidence
	Solar Angle	Solar Angle
	Channel Morphology Features:	Channel Morphology Features:
	Streambank Alteration	Streambank Alteration
	Vegetative Stability	Vegetative Stability
	Undercut	Undercut
	Channel-bank Angle	Channel-bank Angle
	Stream Bottom Features:	Stream Bottom Features:
	Gradient	Gradient
	Sinuosity	Sinuosity
	Substrate Particle Size	Substrate Particle Size
	Embeddedness	Embeddedness
	Channel Vegetative Cover	Channel Vegetative Cover
	Riparian Zone Features:	Riparian Zone Features:
	Streamside Cover	Streamside Cover
	Vegetative Use	Vegetative Use
	Vegetation Overhang	Vegetation Overhang
	Habitat Type	Habitat Type
	Macroinvertebrate Species Composition	Fish Population Features:
		Species Composition
		Estimation of Number
		Length
		Weight

five sampling stations in this area to classify aquatic habitat. In 1985 and 1986, habitat assessments were conducted on portions of the Lamar River upstream from the confluence with the Little Lamar River. This study area was termed "upper Lamar River". A reconnaissance-level survey was conducted on nine reaches of the upper Lamar River mainstem and six stream reaches of the Little Lamar River (Figures 15 and 16). In 1986, cursory-level surveys were conducted on 15 Lamar River tributaries (Figure 17) and on 9 Little Lamar River tributaries.

Upper Lamar River

Physical

The upper Lamar River drainage was formed by andesitic and basaltic flows of the Wapiti formation during the Eocene Absaroka volcanic activity. Some of the highest mountains in YNP are adjacent to these headwater areas. The Pinedale glaciation covered the drainage with a rubble veneer and volcanic till that averages less than 1.5 m in depth; the Hoodoo formations are remnant Eocene bedrock outcroppings formed by glacial activity.

Lodgepole pine (*Pinus contorta*) is dominant throughout the riparian zone of the upper Lamar River. The steep, high elevation slopes bordering the river are covered primarily with whitebark pine (*Pinus albicaulis*) interpersed with Engelmann spruce (*Picea engelmanni*). Numerous talus slopes and frequent rockslide activity have resulted in bare areas scattered throughout the entire upper Lamar River watershed.

Due to the heavily timbered slopes of the upper Lamar River watershed, access is restricted primarily to big game trails. Evidence of use by deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and moose (*Alces alces*) was noted in nearly all of the stream reaches. On 26 July 1985, fresh bear (*Ursus* sp.) tracks were seen in Reaches 4 and 5 (Figure 15). A porcupine (*Erethizon dorsatum*) was also seen at the river's edge on this date. Water ouzels (*Cinclus mexicanus*) were the most common type of bird observed in the riparian area. During the reconnaissance survey of Reach 11, a nest with an unidentified flycatcher and four young was discovered in the canyon near the flow transect.

Since the habitat assessment encompassed two field seasons, total comparability among stream reaches is not possible for all habitat features, particularly streamflow; however, generalized comparisons can be

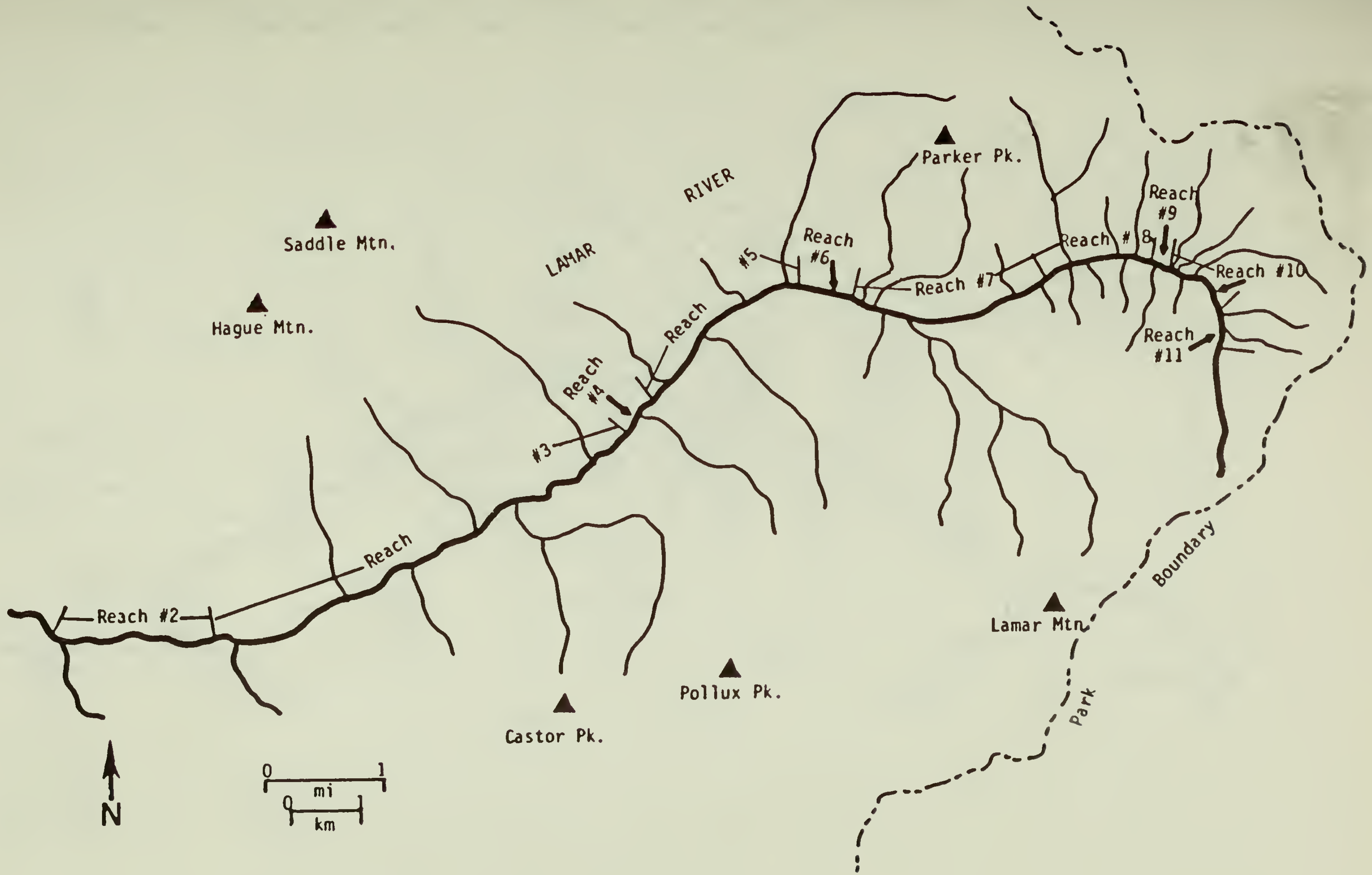

Figure 15. Stream reaches of the Upper Lamar River, 1986.

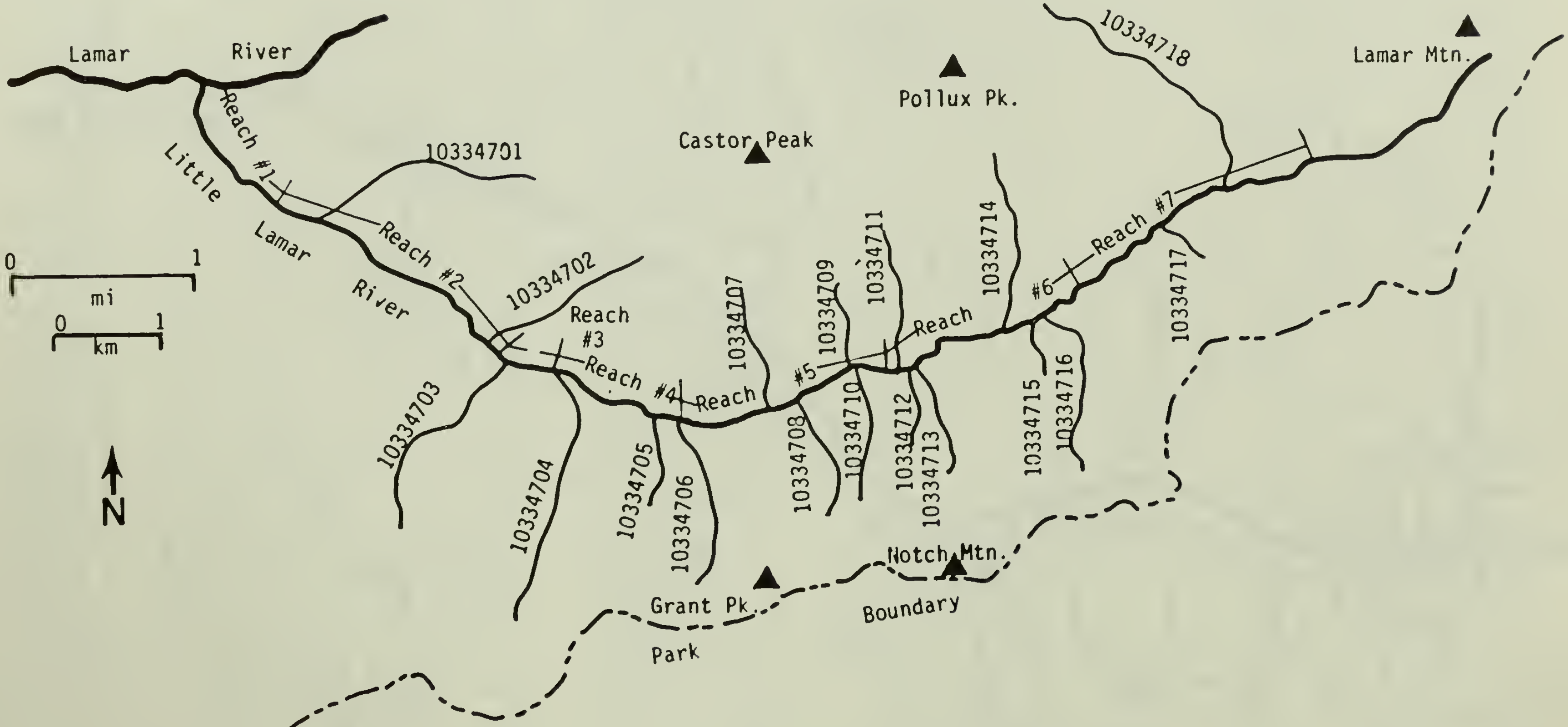

Figure 16. Hydrographic map of the Little Lamar River, 1986.

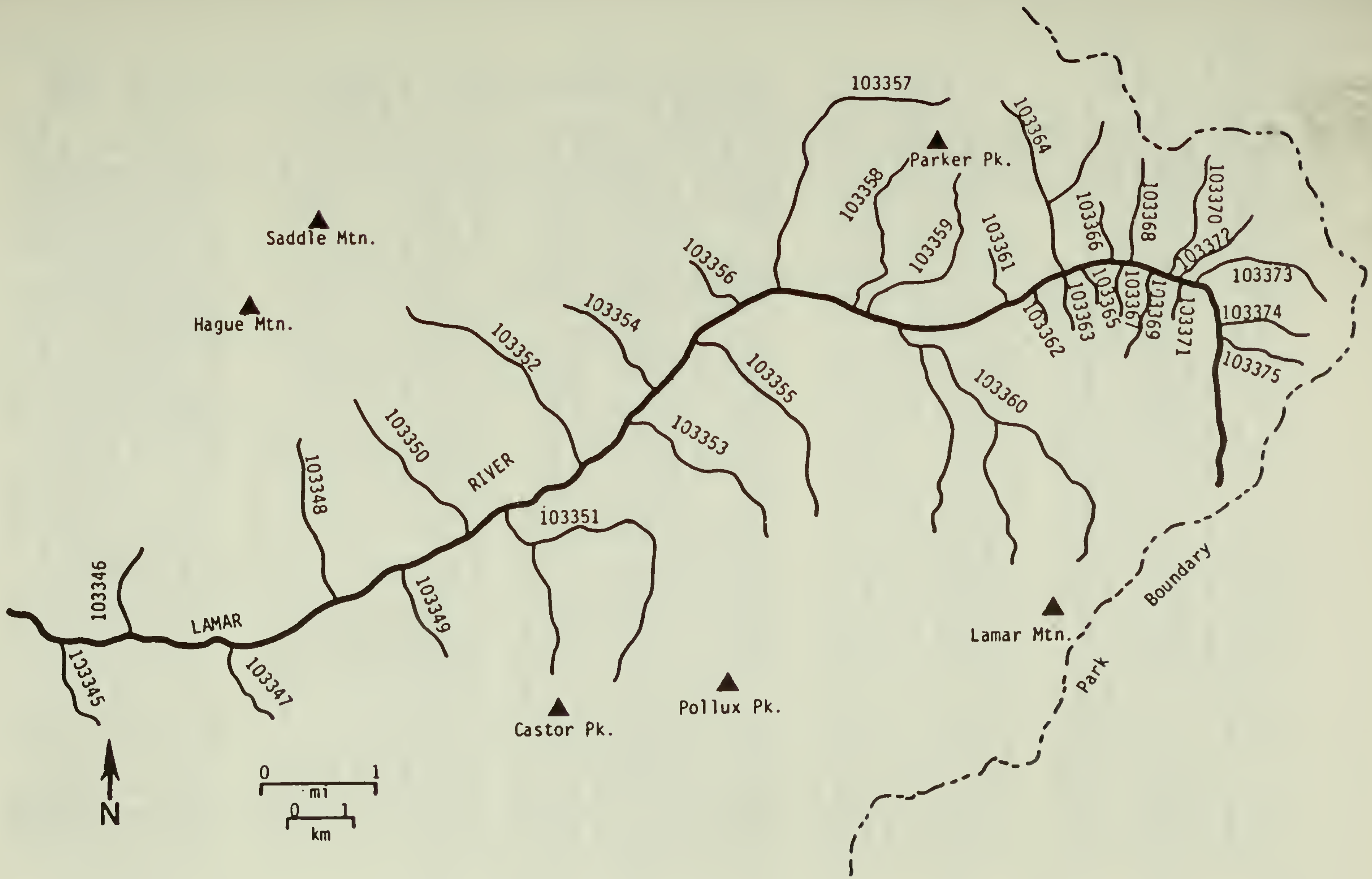

Figure 17. Tributaries of the upper Lamar River, 1986.

made. The upper three stream reaches (9, 10, and 11) were classified as second order stream sections, and the remaining stream reaches represented third order stream segments. The majority of the Lamar River is low gradient (< 5%). Only in the headwater portions does the gradient become steeper (Table 23). Reaches 9 and 11 are formed in narrow bedrock canyons and display many similarities; the remaining stream reaches are quite different in a number of habitat features.

The Lamar River is characterized by a highly erosive channel and flood damage is extensive. With the exception of the canyon reaches (9 and 11), channel instability, downed timber, and shifting substrate best describe the lotic habitat. Large channel-bank angles coupled with minimal or complete absence of undercut banks typify the upper Lamar River. Streambank composition ranges from a rubble-gravel mixture to tree roots and grass.

In general, streambank vegetation is only in fair condition. Riparian vegetation adjacent to the stream often had exposed roots. The large amount of newly downed timber throughout the stream channel underscores the instability of the streambanks during peak flows. As a result, several sections of streambank are devoid of vegetation, and vegetation overhang is minimal throughout the upper Lamar River. Relatively high solar angles give evidence of the openness of the stream channel and minimal influence of the riparian zone in the lower stream reaches.

The high ratios between high water mark (channel width) and stream width indicate frequent flooding, poor channnel development, and only a limited amount of streambank stability. This situation is most notable in the lower reaches (3 through 6) and in Reach 10. For the vast majority of the upper Lamar River, streambank alteration is extensive and ranges from a low of 24.2% in Reach 3 to 50.3% in Reach 5 (Table 23). The two bedrock canyon sections (Reachs 9 and 11) had only minimal streambank alteration.

Cobble is the dominant substrate downstream from Reach 9. Smaller substrate sizes (gravel, sand, or silt) occur infrequently in the stream channel during low summer flows; however, exposed high water portions of the stream bottom are composed predominately of smaller substrate particles. Thus, there exists a high potential for significant sediment input into the upper Lamar River during periods of increased streamflow. The upper three reaches contain significant amounts of

Table 23. Habitat characteristics of the upper Lamar River, 1985-86.

	Lamar River (Stream 1033)								
Habitat Features	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Sample Date	07/29/85	07/26/85	07/26/85	07/25/85	07/25/85	08/09/86	08/09/86	08/08/86	08/08/86
Time	1115	1445	1000	1700	1445	1600	1230	1215	1130
Stream Order	III	III	III	III	III	III	II	II	II
Length (km)	6.0	0.6	2.0	1.0	1.2	1.4	0.2	1.1	0.5
Elevation:									
Maximum (m)	2380.5	2388.1	2444.5	2468.9	2560.3	2625.9	2645.7	2706.6	2755.4
Minimum (m)	2261.6	2380.5	2388.1	2444.5	2468.9	2560.3	2625.9	2645.7	2706.6
Drainage Size (ha)	11084.6	5052.0	4768.5	4036.1	3414.0	1712.9	1023.8	956.9	413.5
Water Column:									
Flow (m3/s)	0.216	0.204	0.242	0.288	0.115	0.246	0.119	0.063	0.056
Channel Width (m)	19.6	16.9	30.8	11.0	10.5	15.1	5.5	10.0	6.7
Stream Width (m)	9.0	4.2	6.9	4.8	5.8	5.5	2.8	3.9	2.3
Stream Depth (cm)	12.19	18.29	12.19	13.72	9.14	15.24	48.77	15.24	9.14
Stream Shore Water Depth (cm)	9.14	6.10	3.05	5.49	3.05	0.91	0.00	0.00	0.00
Riffle Width (m)	7.62	3.29	4.30	3.38	3.62	1.52	0.58	0.76	0.44
Pools:									
Width (m)	0.7	0.7	1.1	1.0	1.1	1.2	1.1	1.1	1.9
Quality	1.2	1.5	1.4	1.4	1.8	1.5	2.9	1.4	1.7
Feature	3.2	2.6	3.4	1.2	3.3	3.7	4.0	4.0	4.0
Solar Angle	107.3	82.3	99.3	81.0	91.3	83.3	49.7	66.7	57.3
Channel Morphology									
Streambank Alteration	24.2	28.3	50.3	29.2	37.5	28.3	1.7	49.2	10.8
Vegetative Stability	2.2	2.7	2.2	2.7	3.2	2.8	4.0	2.2	3.8
Undercut (cm)	6.1	30.5	0.0	0.0	3.0	3.0	6.1	0.0	0.0
Channel-Bank Angle	138.3	115.0	150.0	145.8	138.3	120.6	125.0	124.0	144.2
Stream Bottom:									
Gradient (%)	1.3	1.8	2.2	2.3	1.8	3.8	5.3	6.0	10.0
Sinuosity	1.06	1.09	1.11	1.10	1.05	1.10	1.20	1.30	1.16
Substrate:									
Boulder >356 mm	5.7	28.0	30.2	40.4	22.7	21.8	56.2	51.7	45.5
Cobble 64-356 mm	83.5	40.4	59.1	51.3	77.3	67.3	25.5	32.8	36.4
Gravel 2-64 mm	10.8	31.6	3.0	8.3		9.1	7.3	2.6	13.6
Sand 0.6-2 mm			0.0			1.8	7.3		
Silt <0.6 mm			7.5				3.6	12.9	4.5
Embeddedness	3.30	4.00	4.70	3.30	3.30	3.00	3.30	4.00	3.67
Channel Vegetative Cover (cm)	0.00	15.24	0.00	0.00	18.29	0.00	3.05	0.00	0.00
Riparian Zone:									
Streamside Cover	2.2	1.7	1.2	2.3	1.2	1.8	3.0	2.0	1.0
Vegetative Use	5.80	8.30	5.80	19.20	11.70	13.30	1.70	9.20	4.17
Vegetation Overhang (cm)	9.14	0.00	0.00	12.19	0.00	15.24	7.62	0.00	0.00
Habitat Type	13,9	12,13	11	11,12	12	8,13	12,13	2,13	12

bedrock and large boulders and appear to contribute less sediment to the stream.

Substrate embeddedness was quite low throughout all surveyed stream reaches. Due to recurring high water flood damage and general channel instability, the substrate is potentially "mobile", and higher streamflows appear to move all substrate size classes with ease.

Pools are infrequently formed and are generally of limited quality. The majority of the pools in the upper Lamar River are shallow, formed by cobble or boulders, and provide only minimal instream cover for fish. Reaches 4, 6, 9, and 11 have steep canyon walls on one or both sides of the channel, resulting in pools of up to 1.25 m in depth which provide good cover for fish. In the remaining stream sections instream cover is restricted to abundant downed timber in the stream channel.

Upper Lamar River streamflows in 1986 were higher than those in 1985 (Table 23). Discrepancies in the general pattern of increasing streamflows from headwaters to mouth occurred in Reaches 3, 4, and 5 in 1985. Two possible explanations are the highly variable weather (a day long rain followed by hot, clear weather with subsequent dropping stream level during the 1985 survey) and underground flow into the exposed areas of the unstable stream channel.

Numerous debris jams formed by runoff floods would appear to be temporary barriers to fish movement. A small (1.5 m high) waterfall between Reach 9 and 10 may possibly function as a barrier at low streamflows; however, trout were observed or collected in all survey reaches except for the uppermost reach. Reach 11 contains several high waterfalls and cascades that are a complete barrier to fish movement. Some pools in this section were rated excellent, due to their large size and depth. Reach 11 was sampled for fish, but none were collected or observed.

Tributaries to the upper Lamar River have steep gradients (range: 13.3% - 38.1%). Mean tributary water temperature in 1986 was 9.7 C. Cursory surveys revealed that the majority of the tributaries are relatively short, less than 2 m in width, and provide only a minimal contribution to the mainstem streamflow. Tributaries 103368 and 103373 had the highest streamflows in 1986 (Table 24), although tributary 103360 had the greatest streamflow of all upper Lamar

Table 24. Physical features of tributaries to upper Lamar River and Little Lamar River, 1986.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
Upper Lamar River Tributaries											
103361	I	70.90	0.60	2731.0	2535.9	32.5					8
103362	I	21.70	0.40	2633.5	2551.2	20.6					8
103363	I	31.50	0.80	2877.3	2569.5	38.1	0.0030	0.43	3.35	17.56	5
103364	II	362.28	2.41	2891.0	2571.0	13.3	0.0070	1.97	3.35	10.00	14
103365	I	31.50	0.80	2865.1	2579.2	35.8	0.0067	0.63	9.45	11.23	12
103366	I	35.00	0.80	2889.5	2599.9	36.2					
103367	II	31.50	1.00	2962.7	2609.1	35.4	0.0200	1.62	4.26	28.43	7
103368	I	189.00	1.41	2944.4	2618.2	23.1	0.0630	2.25	9.44	29.81	9
103369	I	357.00	1.17	2938.3	2635.0	25.9	0.0007	0.43	3.05	5.18	6
103370	I	162.80	1.77	2944.4	2645.7	16.9	0.0100	1.18	7.00	11.98	7
103371	I	23.60	0.80	2877.3	2648.7	28.6	0.0058	1.15	6.09	8.22	7
103372	I	39.40	1.20	2926.1	2657.9	22.4	0.0176	2.12	7.92	10.50	7
103373	I	294.00	2.00	3041.9	2664.0	18.9	0.1174	2.81	16.14	25.89	13
103374	I	27.60	1.00	3096.8	2720.3	37.7	0.0034	0.80	2.74	15.62	15
103375	I	162.80	1.34	3060.2	2731.0	24.6	0.0045	0.98	3.35	13.57	11
Little Lamar River Tributaries											
10334705	I	23.60	0.80	2755.4	2478.0	23.6	0.0018	0.77	3.05	7.80	8
10334706	I	118.10	1.50	2836.2	2483.8	23.5	0.0560	2.12	10.06	25.91	7
10334708	I	39.40	1.20	2863.6	2561.8	25.2	0.0075	1.01	6.71	11.03	11
10334710	I	59.10	1.30	2877.3	2596.9	21.6	0.0021	0.72	3.35	8.51	11
10334711	I	326.10	1.00	2828.5	2613.7	21.5	0.0024	0.83	3.96	7.20	7
10334712	I	17.70	1.00	2926.1	2621.3	30.5	0.0139	0.96	4.27	34.03	5
10334713	I	288.80	1.14	2846.8	2624.3	19.5	0.0771	1.69	13.72	33.27	4.5
10334714	I	272.50	1.40	3072.4	2654.8	29.8					
10334716	I	315.00	1.60	2904.7	2670.0	14.7					
10334718	I	215.80	2.50	3041.9	2724.9	12.7	0.0542	1.62	10.97	30.50	11

River tributaries sampled in either 1985 or 1986. This stream contributes approximately 50% of the total upper Lamar River flow. The confluence has a Y-shaped appearance stemming from the similar streamflows in both tributary 103360 and the Lamar River mainstem.

Tributary streams 103361, 103362, 103363, 103366, 103369, and 103375 had bedrock channels and were similar to large vegetated springs in appearance. The remaining nine streams surveyed in 1986 had unstable channels resulting from high water flood damage. In general, the larger, longer tributaries were subject to the most channel degradation. Tributary 103368 exhibited the most deterioration. The appearance of this tributary was very similar to the highly impacted reaches in the mainstem.

Several dry runoff channels were noted in most reaches during the survey period in both 1985 and 1986. Exposed cliffs, with a great potential for mass wasting, and deep (7-10 m), silty side channels present substantial sediment input potential during peak flows. These dry runoff channels were most numerous in the lower survey sections (Reaches 3, 4, and 5) adjacent to the southeast slopes of Hague Mountain and Saddle Mountain.

Chemical

Extensive chemical analyses were conducted on water samples from four sites in the upper Lamar River watershed (Table 25). The upper Lamar River mainstem site was located approximatley 15 m upstream from tributary 103375 (Figure 17). Additional samples were collected approximately 50 m from the mouth of tributaries 103360, 103368, and 103373. The upper Lamar River and tributaries were classified as sodium-potassium bicarbonate waters. All are dilute streams (total dissolved solids (TDS) less than 50 mg/l). Limited production would be expected in these waters.

Biological

Macroinvertebrates

Over 20 species of macroinvertebrates were collected from the upper Lamar River (Table 26). Ephemeropterans, Plecopterans, and Trichopterans showed the highest mainstem species diversity. Increasing channel instability of the upper Lamar River was reflected by the low species diversity found in the lower stream reaches (3-7). Ephemeropterans and Dipterans are dominant in the lower reaches, but Trichopterans are

Table 25. Chemical characteristics of backcountry streams surveyed, Lamar River drainage, Yellowstone National Park, 1986.

	Upper Lamar River	103361	103368	103373	Little Lamar River	10334713	Parkwide Streams Mean	SE	Minimum	Maximum
Water Temperature (C)	7	11	13	13	11	4	10.50	0.48	0.00	20
Spec. Cond (μmhos)	49	64	62	58	64	61	150.03	17.81	4.90	1000
pH	7.3	7.3	7.4	7.4	7.2	7.3	7.70	0.07	4.50	8.75
Total Alkalinity	24.0	26.0	32.0	20.0	36.0	26.0	69.60	6.38	0.90	401
Ca Hardness	5.04	8.86	3.97	3.77	9.46	15.4	38.71	4.06	2.00	193
Total Hardness	<9.16	15.20	9.65	<7.89	15.4	23.4	57.64	6.02	4.00	281
Total Dissolved Solids	22	26	25	20	29	27	101.24	10.88	15	690
Carbonate Alkalinity	0	0	0	0	0	0	0	0.00	0	0
Bicarbonate Alkalinity	24.0	26.0	32.0	20.0	36.0	26.0	69.60	6.38	0.90	401
Carbonates	0	0	0	0	0	0	0	0.00	0	0
Bicarbonates	29.3	31.7	39.0	24.4	43.9	31.7	78.50	6.09	1.22	300
Hydroxides	0	0	0	0	0	0	0	0.00	0	0
Carbon dioxide	2.2	2.3	3.2	2.6	3.5	3.3	-	-	-	-
Chloride	1.96	<1.0	<1.0	<1.0	2.0	<1.0	5.65	1.61	0.90	104
Sulfate	2.0	2.3	2.3	1.0	5.7	1.8	13.45	3.09	0.60	165
Fluoride	0.057	0.064	0.081	0.055	0.118	0.060	0.87	0.17	0.04	8.20
Potassium	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.73	0.61	0.16	39
Mg Hardness	<4.12	6.34	5.68	<4.12	5.93	8.03	-	-	-	-
Calcium	2.02	3.55	1.59	1.51	3.79	6.16	15.42	1.60	0.80	77.20
Magnesium	<1.00	1.54	1.38	<1.00	1.44	1.95	4.63	0.53	0.09	26.50
Sodium	8.0	8.0	11.0	7.0	9.0	4.0	12.60	2.59	0.50	186
Iron	0.23	0.49	0.80	0.28	0.22	0.14	0.26	0.03	0.01	1.90
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.00	0.01	0.17
Copper	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.01	0.29
Silica	5.9	7.0	8.1	6.8	8.0	8.3	11.39	1.48	1.30	98
Color (PCU)	0	5	5	0	0	0	-	-	-	-
Turbidity (NTU)	1.8	1.8	3.5	0.4	2.4	0.0	1.91	0.33	0	24
TOC	0.3	4.6	<0.1	9.9	106	95.1	5.24	1.24	0.10	95.10
Ortho-phosphate	0.18	0.09	0.12	0.05	0.21	0.24	0.09	0.02	0.01	0.93

Table 26. Occurrence and densities of macroinvertebrates found in stream reaches, Upper Lamar River, 1985 and 1986.

Reach No.	3	4	5	6	7	8	9	10	11
Insecta									
Ephemeroptera (mayflies)									
Siphlonuridae									
Ameletus sp.								1	
Baetidae									
Baetis bicaudatus			1	2			1	1	4
Heptageniidae									
Cinygmula sp.		2	8	2		11	13	1	3
Rithrogena sp.	2						4	22	6
Epeorus albertae								3	
Epeorus deceptivus	8			15		3	2		
Ephemerellidae									
Drunella coloradensis	2								
Drunella doddsi						2			
Seratella mitchneri	1								
Plecoptera (stoneflies)									
Nemouridae									
Zapada sp.									3
Nemoura sp.									2
Perlodidae		2							
Megarcys sp.								5	5
Chloroperlidae					1	1	1	3	
Trichoptera (caddisflies)									
Rhyacophilidae									
Rhyacophila sp.								1	5
Glossosomatidae									
Anagapetus sp.							2		
Hydropsychidae									
Arctopsyche grandis							1		
Limnephilidae									
Apatania sp.								2	
Diptera (true flies)									
Tipulidae									
Tipula sp.						2	1		
Rhabdomastix sp.					3				
Chironomidae				1	3		1		1
TOTAL TAXA:	4	2	2	4	3	5	9	9	8
TOTAL:	13	4	9	20	7	19	26	39	29

noticeably absent. Cinygmula sp. was the most common mainstem macroinvertebrate collected. This species was collected in all survey reaches except Reach 3 and Reach 7. The mainstem reaches had slightly higher macroinvertebrate densities (mean = 18.4) than the tributaries (mean = 13.1).

Ephemeroptera was the dominant order found in the tributaries (Table 27). Baetis bicaudatus was the most commonly found species in the tributaries, and Cinygmula sp. was the second most common. Numerous Chloroperlidae were also collected in the tributaries. Dipterans are well represented in the tributaries (Table 27) and three species of Tipulids were collected. Tributary 103364 exhibited the highest species diversity, while tributary 103373 showed the greatest invertebrate density. Although these two streams show signs of flood damage, they are two of the larger tributaries to the upper Lamar River. In contrast, stream 103368 had the lowest species diversity of any upper Lamar River tributary. This stream also exhibited the greatest degree of channel degradation.

Aquatic Vertebrates

In 1986, fish were collected in the upper Lamar River. Five cutthroat trout (Salmo clarki bouvieri) with a mean length of 242 mm (range: 202-235 mm) were captured in Reach 10 of the upper Lamar River. Cutthroat trout growth patterns were similar in both the upper Lamar River and the Little Lamar River (Table 28).

Angler Use

Angler use on the upper Lamar River appears to be minimal. Volunteer Angler Report (VAR) data indicate that the upper Lamar River angler use is between 25 and 30 angler days/year. Reported landing rates were approximately 2.1 fish/hr and all fish caught were less than 250 mm.

Little Lamar River

Physical

The Little Lamar River is the major tributary of the Lamar River upstream from Cold Creek (Figure 18). The geological forces of Absaroka volcanics and subsequent Pinedale glaciation are manifested in the Little Lamar River. Notch Mountain and Grant Peak exhibit Lava Creek tuff influences. The large headwater meadow in the Little Lamar River is the remnant glacial fan outwash,

Table 27. Occurrence and densities of macroinvertebrates found in tributaries to the Lamar River, 1986.

Tributary No. 1033	64	65	66	68	69	70	71	72	73	74	75	76
Insecta												
Ephemeroptera (mayflies)												
Siphlonuridae												
Ameletus sp.	1	2		1			1		3			3
Baetidae												
Baetis bicaudatus	1		[illegible]	4	3		3		13	2	3	15
Heptageniidae												
Cinygmula sp.	1	1	2		5				12	10	4	
Epeorus deceptivus		1					1		9			
Plecoptera (stoneflies)												
Nemouridae												
Zapada sp.	6	1					2					
Visoka cataractae	2											
Capniidae												
Isocapnia sp.									1			
Perlodidae												
Megarcys sp.							1	2	1			
Chloroperlidae	3				1				3	8		4
Trichoptera (caddisflies)												
Rhyacophilidae												
Rhyacophila sp.									5			
Hydropsychidae												
Arctopsyche grandis					1							
Lepidostomatidae												
Lepidostoma sp.	1											
Limnephilidae												
Neothremma alicia	2											1
Homophylax sp.												
Imania sp.	3											
Coleoptera (beetles)												
Staphylinidae						1					1	
Diptera (true flies)												
Tipulidae												
Antocha sp.	3											
Dicranota sp.						1						
Tipula sp.	2	1							1			2
Simuliidae												
Prosimulium sp.			2			1		1				
Chironomidae	7						9					1
Ephydridae											1	
Pelecypoda												
Pisidium sp.								3				
TOTAL TAXA:	12	5	4	2	4	3	6	3	9	3	4	6
TOTAL:	32	6	7	5	10	3	17	6	48	20	9	26

Table 28. Back-calculated mean length at annulus formation of Lamar River drainage salmonids, 1986.

Survey Section	Species	Sample Size	Length (mm) at Age I	II	III	IV	V
Upper Lamar River	Cutthroat	5	76	132	176	223	257
Little Lamar River	Cutthroat	11	63	116	171	205	256
Lamar River confluence with Soda Butte Creek	Rainbow x Cutthroat Hybrid	4	61	123	190	263	
Soda Butte Creek (upper)	Rainbow x Cutthroat Hybrid	6	75	130	190	238	
Soda Butte Creek (lower)	Rainbow x Cutthroat Hybrid	19	68	115	175	231	292
Warm Creek	Rainbow x Cutthroat Hybrid	2	68	108			

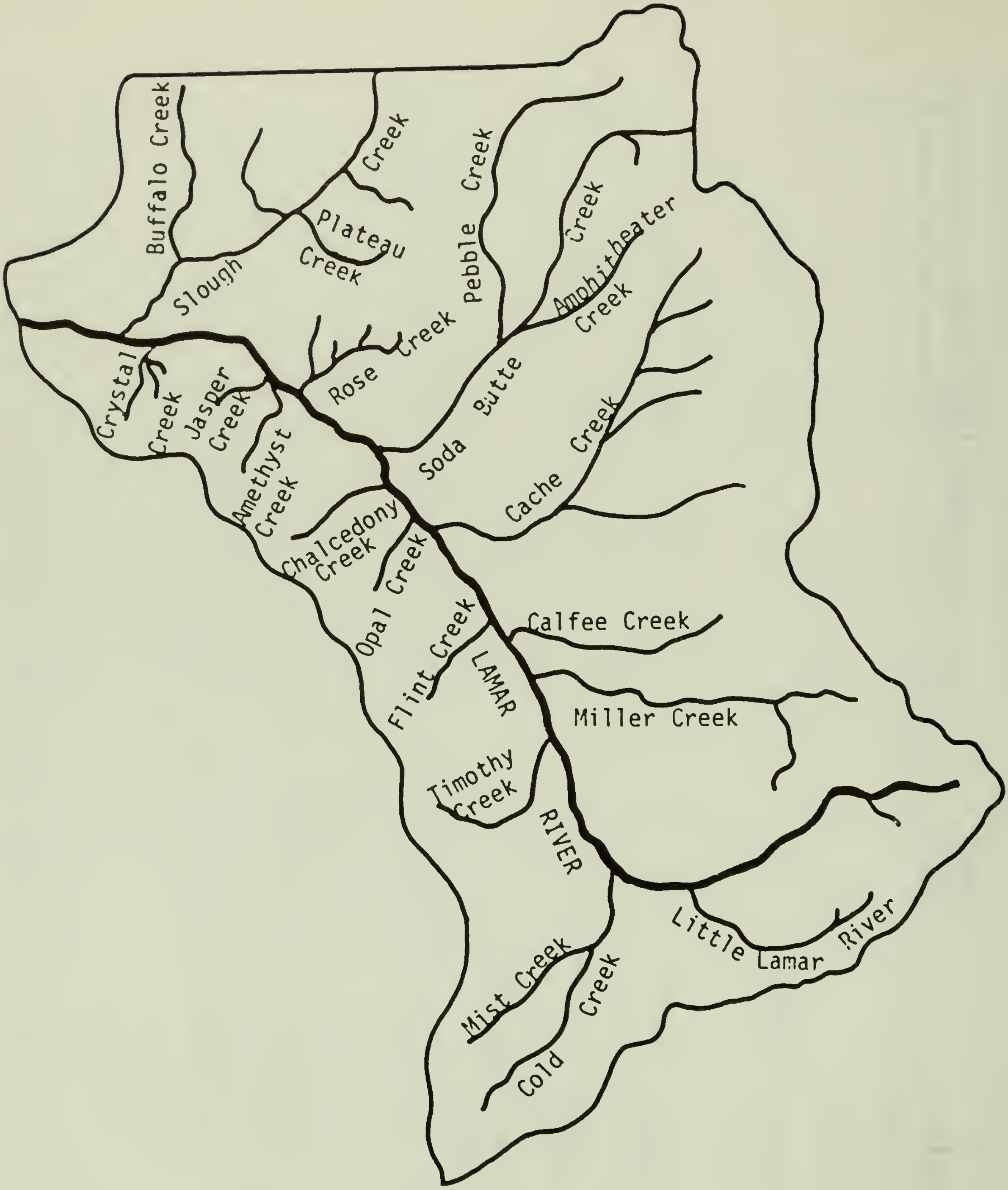

Figure 18. Named streams in the Lamar River drainage, YNP.

and present streams represent trenches through the glacial deposits (Pierce 1974).

Lower stream reaches of the Little Lamar River are contained in a dense lodgepole pine forest. Deadfall covers both the stream channel and the riparian zone, so access is quite difficult. The uppermost reach (7) is enclosed in a large meadow bordered by Lamar Mountain and Pollux Peak.

Elk and moose tracks were observed throughout the entire survey area. Although the headwater meadow had the highest ungulate vegetative use rating of any survey reach in the upper Lamar River drainage (Table 29), use was rated as light to moderate. In 1985, bear activity was noted in Reach 2 and Reach 3. A pine marten (Martes americana) was seen during the reconnaissance survey of Reach 6. Juncos (Juncos sp.) and nuthatches (Sitta canadensis) were the most commonly observed avian species in the riparian forest. Water ouzels (Cinclus mexicanus) and an unidentified sandpiper were restricted to the stream channel.

Little Lamar River is similar to the upper Lamar River in stream width and general appearance. However, channel width is smaller, particularly in the lower reaches at the western base of Castor Peak (Table 29). Channel instability, flood damage, and numerous raw banks are common in these lower reaches (2 through 5). Vegetative stability ranked low and undercut banks were rare. The potential for sediment input is great. On 27 July 1985, the Little Lamar River changed from a clear stream to a highly turbid stream after only 30 minutes of rain.

Pools are numerous throughout the river, but they are primarily small, shallow, and of fair quality. Cobble, boulders, and downed timber form the vast majority of the pools. Reach 6 contained several high quality pools, but they were not within the transects. Large debris jams of downed timber are common in the lower stream reaches but do not appear to be barriers to fish movement, since fish were observed or collected in all reconnaissance survey reaches in the Little Lamar River.

Low substrate embeddedness underscores the general instability of the channel throughout the river. Unstable conditions that characterize the Little Lamar River are primarily due to the alluvial composition of the watershed. Evidence of resistance to high water channel erosion was limited to Reaches 6 and 7.

Table 29 . Habitat characteristics for the Little Lamar River, 1985-86.

	Little Lamar River (Stream 103347)					
	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Sample Date	07/28/85	07/28/85	07/27/85	08/12/86	08/12/86	08/11/86
Time	1330	0900	1500	1215	0830	1530
Stream Order	II	II	II	II	II	II
Length (km)	3.2	1.1	0.4	2.0	2.0	2.4
Elevation:						
Maximum (m)	2412.5	2471.9	2487.2	2609.1	2677.7	2755.4
Minimum (m)	2304.3	2412.5	2471.9	2487.2	2609.1	2677.7
Drainage Size (ha)	3122.2	2748.1	2401.6	2106.3	1744.0	1075.0
Water Column:						
Flow (m3/s)	0.391	0.348	0.232	0.260	0.143	0.088
Channel Width (m)	11.9	11.9	15.5	12.8	15.4	12.0
Stream Width (m)	5.1	4.8	4.1	4.3	5.3	4.4
Stream Depth (cm)	15.24	15.24	15.24	15.24	9.14	9.14
Stream Shore Water Depth (cm)	6.10	9.14	9.14	0.91	6.10	0.91
Riffle Width (m)	3.66	2.65	2.69	1.68	2.00	1.52
Pools:						
Width (m)	0.9	0.9	0.8	1.1	1.0	0.8
Quality	1.7	1.1	1.5	1.6	2.0	1.9
Feature	3.3	3.2	4.3	2.8	3.6	3.2
Solar Angle	72.0	87.7	61.0	54.7	40.0	82.7
Channel Morphology						
Streambank Alteration	38.3	58.3	51.7	39.2	30.0	30.8
Vegetative Stability	2.3	1.5	1.5	2.3	3.0	3.5
Undercut (cm)	0.0	0.0	0.0	6.1	21.3	0.9
Channel-Bank Angle	128.3	150.0	140.0	126.7	124.2	124.5
Stream Bottom:						
Gradient (%)	2.7	2.0	2.8	5.0	4.2	2.8
Sinuosity	1.30	1.10	1.20	1.15	1.28	1.17
Substrate:						
Boulder >356 mm	25.9	32.0	25.0	23.8	7.7	9.0
Cobble 64-356 mm	74.1	47.4	70.0	52.4	48.1	32.0
Gravel 2-64 mm		20.6	5.0	11.9	42.3	52.2
Sand 0.6-2 mm				4.8		6.8
Silt <0.6 mm				7.1	1.9	
Embeddedness	4.00	3.00	3.70	3.70	3.33	3.70
Channel Vegetative Cover (cm	0.00	0.00	0.00	6.10	9.14	12.19
Riparian Zone:						
Streamside Cover	2.5	1.8	2.3	2.8	2.3	1.3
Vegetative Use	5.80	8.30	5.80	10.80	16.70	24.20
Vegetation Overhang (cm)	12.19	0.00	6.10	0.00	12.19	9.14
Habitat Type	11,13	8,12	8,12	13	12,2	9

Although the drainage basin of Little Lamar River is considerably smaller than that of the upper Lamar River, streamflows in the Little Lamar River were greater than those of the upper Lamar River in 1985. Streamflow in Reach 2 was nearly double that of the Lamar River at the confluence with the Little Lamar River (Tables 27 and 29). However, this may be a reflection of heavy rains rather than normal streamflow patterns.

All tributaries to the Little Lamar River were first order streams, with high gradient, narrow stream widths (< 1 m), and minimal streamflow (Table 24). Streams 10334705, 10334708, and 10334712 have bedrock channels and contain abundant vegetation in the stream channel. Most of the other tributaries have the appearance of steep runoff channels. Highly erosive banks and large amounts of debris (trees and boulders) characterize these tributaries. Tributary 10334716 was dry on 11 August 1986. This runoff channel from Notch Mountain contained many large boulders at the confluence with the Little Lamar River. Stream 10334713 exhibited the largest streamflow of the tributaries (Table 24). In the headwater meadow, numerous tributaries similar to stream 10334718 contribute substantial streamflow to the Little Lamar River mainstem. Cursory-level surveys were not conducted on these headwater tributaries. In addition to the surveyed tributaries, several springs were scattered throughout the upper two stream reaches. These were not surveyed due to short stream length (less than 100 m).

Chemical

Extensive chemical analyses were conducted on water samples from two sites in the Little Lamar River watershed (Table 25). The Little Lamar River sample was collected 100 m upstream from stream 10334718. An additional sample was collected near the mouth of tributary 10334713.

Little Lamar River samples were dilute waters and differed only to a minor degree from samples of the upper Lamar River. Tributary 10334713 was classified as a dilute calcium-bicarbonate stream. The higher calcium concentrations in this stream may reflect a local glacial debris or andesitic influence from Notch Mountain. The 1986 analyses are very similar to samples collected in 1984 (Jones et al. 1985); thus, it appears that annual chemical fluctuations in the Little Lamar River and upper Lamar River drainages are minimal.

Biological

Macroinvertebrates

Benthic macroinvertebrate distribution in the Little Lamar River is similar to that found in the upper Lamar River (Table 30). Ephemeropterans and Plecopterans are dominant in the mainstem. Only two Trichopteran species were collected. Although macroinvertebrate production should be greater in the lower sections of a stream (Vannote et al. 1980), species diversity in the unstable lower stream reaches was slightly less than that found in the headwater sections. Epeorus sp. was much more common in Little Lamar River than in upper Lamar River. Species composition in the tributaries shifted from predominately Ephemeropterans in streams 10334705 and 10334708 to a combination of Dipterans, Plecopterans, and Ephemeropterans in streams 10334712 and 10334713. In addition to being the largest tributary to Little Lamar River, tributary 10334713 exhibited the highest macroinvertebrate density of any sample site in the upper Lamar River watershed. Nearly half of the specimens in this sample were Chironomids.

Most macroinvertebrate species collected in the upper Lamar River drainage are sensitive to fluctuations in water chemistry and habitat type. However, the most sensitive indicator species (Neothremma alicia, Deuterophleria sp., and Drunella doddsi) were found only in the more stable reaches of the mainstem and tributaries (Tables 26, 27, and 30). The primary substrate composition (cobble and gravel) provides niches for both sensitive and nonsensitive species. The large majority of species collected in the upper Lamar River drainage are classified as collectors and shredders. This arrangement is common in headwater streams of order I-III (Cummins 1977).

Aquatic Vertebrates

Twenty-three cutthroat trout (Salmo clarki) were captured downstream from the headwater meadow of the Little Lamar River. Mean length of these cutthroat trout was 151 mm (range: 48-247 mm). Five year classes were represented in the sample (Table 28).

SODA BUTTE CREEK WATERSHED

Unnamed Tributaries Between Pebble Creek and Lamar River

The Lamar River is the largest tributary to the Lamar River. Approximately 19,425 hectares of the Soda Butte

Table 30. Occurrence and densities of macroinvertebrates found in stream reaches and tributaries of Little Lamar River, 1985-86.

	Stream Reach No.						Tributary 103347						
	02	03	04	05	06	07	05	08	10	11	12	13	18
Insecta													
Ephemeroptera (mayflies)													
Siphlonuridae													
Ameletus sp.	1	2					1	3					
Baetidae		3	4			1	1	2		4		10	2
Baetis bicaudatus													
Baetis tricaudatus										1			
Heptageniidae													
Cinygmula sp.	3	8	21	2		4	2						2
Rithrogena sp.					5		2	10				15	2
Epeorus albertae						5							
Epeorus deceptivus	1			18	4		1					1	
Ephemerellidae													
Drunella coloradensis		1											
Drunella doddsi					2								
Plecoptera (stoneflies)													
Nemouridae													
Zapada sp.		1		13				2	2			4	4
Visoka cataractae												2	
Perlodidae													
Megarcys sp.						4					15	3	1
Chloroperlidae	1											9	
Perlidae													
Doronuria theodora													1
Hempitera (true bugs)													
Gerrinae													
Gerris sp.										1			
Trichoptera (caddisflies)													
Rhyacophilidae													
Rhyacophila sp.				5	1	1		1					
Hydropsychidae													
Arctopsyche grandis					1								
Diptera (true flies)													
Tipulidae													
Dicranota sp.												1	
Deuterophlebiidae													
Deuterophlebia sp.												2	
Simuliidae													
Prosimulium sp.												2	
Chironomidae				11						5	11	39	
Ephydridae												1	
Muscidae						2							
TOTAL TAXA:	4	5	2	5	5	6	5	5	1	4	2	12	6
TOTAL:	6	15	25	49	13	17	7	18	2	11	26	89	12

Creek drainage basin are contained within Yellowstone National Park. Surveys have been conducted on Soda Butte Creek since 1968 to monitor both habitat and fishery responses to pollution effluents from the McLaren mine tailings; however, little work has been conducted on tributaries to Soda Butte Creek. In 1986, cursory-level surveys were conducted on 11 Soda Butte Creek tributaries. Although these tributaries were classified as dry in a previous study (Jones et al. 1982), over 60% of them contained a streamflow in 1986. All of the surveyed tributaries were downstream from the confluence with Pebble Creek (Figure 19).

Physical

Two tributary streams were second order, while the remaining tributaries were first order streams. Stream 10331708 (Trout Lake outlet) had the largest drainage basin area, greatest streamflow, stream width, and the highest pH of the surveyed tributaries (Table 31). Remaining tributaries had streamflows less than 0.05 m^3/s, or were dry when sampled. Five of these tributaries do not form a permanent confluence with Soda Butte Creek. Several of these tributaries sink underground in the flood plain of Soda Butte Creek, and the intermittent runoff channel from Mount Norris (stream 10331706) ends in a large alluvial fan at the edge of the flood plain. Tributary 10331704 exhibits head cutting or "sapping" (W. Hamilton, personal communication, March 1987) approximately 100 m from the confluence with Soda Butte Creek. No fish were observed in any of the tributaries, but one trout sac-fry was collected in stream 10331708 (Trout Lake outlet) in a Surber sample.

Biological

Macroinvertebrates

Trout Lake outlet (stream 10331708) exhibited the greatest productivity of the lower Soda Butte Creek tributaries. Diversity was among the highest and density of macroinvertebrates was nearly double that of any other tributary (Table 32). Trichopterans and Ephemeropterans dominated the species composition in all of the tributaries; however, only two species of Plecopterans were collected. In general, stoneflies are fairly sensitive to environmental fluctuations. The two tributaries where Plecopterans were collected (streams 10331708 and 10331712) appeared to be more stable and subject to less streamflow fluctuation than the other

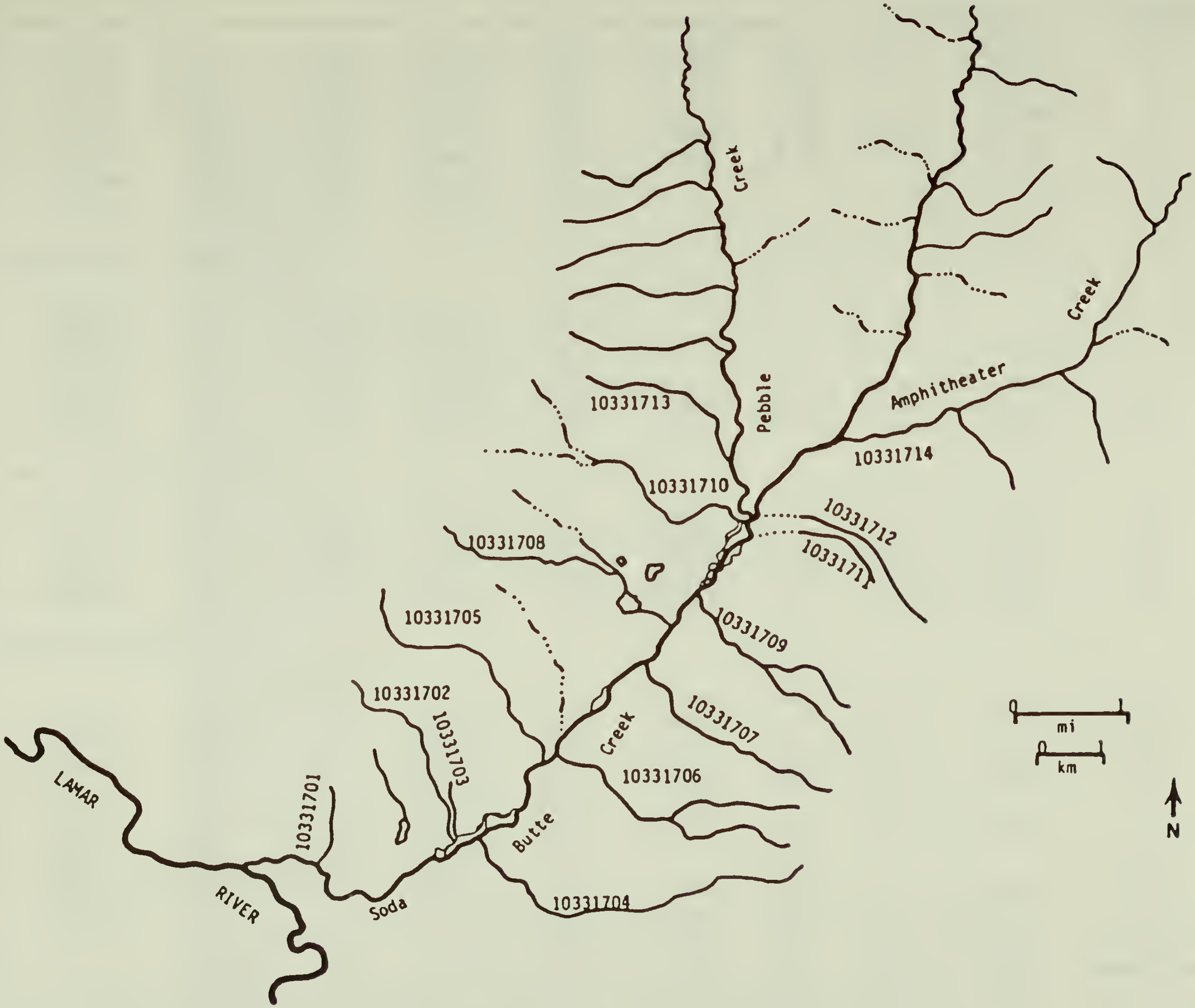

Figure19. Tributaries of lower Soda Butte Creek, 1986

Table 31. Physical features of tributaries to Soda Butte Creek, Pebble Creek, Amphitheater Creek, and Plateau Creek, 1986.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)	pH	Conductivity
1	I	36.60	1.24	2267.7	2011.7	20.6	0.006	0.58	3.05	31.70	17	8.0	>500
2	I	157.50	2.88	2365.2	2014.7	12.2	0.020	0.50	9.75	39.93	13	8.2	260
3	I	26.30	0.74	2072.6	2015.2	7.8					16	8.0	400
4	I	500.10	5.00	2706.6	2017.8	13.8							
5	I	273.00	3.70	2584.7	2036.1	14.8	0.005	0.69	5.18	12.80	8	7.6	315
6	II	259.90	3.60	2657.9	2037.0	17.2							
7	I	221.70	3.20	2779.8	2042.2	23.1	0.010	1.28	7.32	11.28	9	7.2	195
8	I	389.80	3.40	2450.6	2054.7	11.4	0.218	1.81	14.33	84.12	12	8.3	220
9	II	267.80	3.00	2706.6	2058.9	21.6							
10	I	344.50	4.00	2856.0	2066.5	19.7	0.043	1.17	7.62	48.46	8	7.4	150
12	I	110.30	2.30	2950.5	2090.9	37.4	0.010	0.75	7.62	17.07	11	7.3	60
Pebble Creek Tributaries (10331713)													
1033171324	I	127.70	1.20	2591.0	2435.0	13.0	0.036	1.41	9.45	26.82	6	7.2	300
1033171325	I	175.70	1.70	2743.0	2454.0	17.0	0.024	1.40	4.57	36.88	6	8.3	275
1033171326	I	143.70	1.70	2743.0	2513.0	13.5	0.003	0.69	3.05	11.89	10	7.9	312
1033171327	I	143.70	1.40	2789.0	2527.0	18.7	0.020	1.28	7.32	20.73	4	8.0	260
1033171328	I	20.30	0.40	2563.4	2529.1	8.6	0.026	1.18	4.88	44.50	4	7.3	190
Amphitheater Creek Tributaries (10331714)													
1033171401	I	138.30	1.21	2512.0	2210.0	24.9	0.109	1.99	12.80	42.67	8	7.3	59
1033171402	I	133.00	1.48	2615.0	2289.0	22.0	0.001	0.51	3.35	3.05	6	7.3	66
1033171403	I	133.00	1.01	2573.0	2320.0	25.0	0.024	1.37	8.23	21.03	7	7.4	62
1033171404	I	111.70	1.20	2804.0	2451.0	29.1							
1033171405	I	101.10	0.90	2658.0	2505.0	17.6							
1033171406	I	89.20	0.91	2657.9	2511.6	16.3							
1033171407	I	114.20	1.04	2804.1	2535.9	25.8							
Plateau Creek Tributaries (10330210)													
1033021001	I	51.20	1.10	2414.0	2218.9	17.7							
1033021002	I	66.90	1.60	2560.3	2245.8	19.7							
1033021003	I	66.90	1.00	2438.4	2264.7	17.4							
1033021004	I	120.80	1.40	2682.2	2286.0	28.3	0.005	0.58	6.10	14.02	4	8.1	185
1033021005	I	74.80	0.90	2462.8	2298.2	18.3	0.004	0.80	3.81	13.11	7	7.4	147
1033021006	I	346.50	2.50	2822.4	2316.5	20.2	0.017	1.03	11.58	14.33	7	7.4	102
1033021007	I	82.70	1.20	2682.2	2340.9	28.4	0.007	0.36	9.27	19.75	5	6.8	82
1033021008	I	196.90	1.50	2686.8	2382.0	20.3	0.068	1.89	12.27	29.46	9	6.8	50
1033021009	I	374.10	2.60	2816.4	2386.6	16.5	0.139	3.22	15.70	27.57	9	7.0	55

Table 32. Occurrence and densities of macroinvertebrates found in stream reaches and tributaries of Soda Butte and Amphitheater Creeks, 1985 and 1986.

		Soda Butte Creek Tribuary 103317						Amphitheater Creek Reach No.			Amphitheater Creek Tributary 10331714		
	01	02	05	07	08	10	12	01	02	03	01	02	03
Turbellaria													
Annelids	4				4								
Insects													
Ephemeroptera (mayflies)													
Siphlonuridae													
Ameletus sp.												3	2
Baetidae													
Baetis bicaudatus	13	11		4	50	16	1	19	19	4	32		7
Heptageniidae													
Cinygmula sp.				1			3	7	3	4	7	9	
Rithrogena sp.							5	8	4	2			
Epeorus albertae									2				
Epeorus deceptivus		1			1	5	10						15
Epeorus grandis							1	1	1				
Leptophlebiidae													
Paraleptophlebia debilis					4								
Ephemerellidae													
Drunella coloradensis	1	20					1		2		1		
Plecoptera (stoneflies)													
Peltoperlidae													
Yoroperla brevis													2
Nemouridae													
Zapada sp.									1	2		1	2
Malenka sp.					2								
Visoka cataractae													14
Perlodidae													
Megarcys sp.									1	8		1	
Isoperla sobria							1				1		
Isoperla sp.													3
Chloroperlidae									1				
Kathroperla perdita										1			
Perlidae													
Hesperoperla pacificum					2								
Trichoptera (caddisflies)													
Rhyacophilidae													
Rhyacophila sp.		3		1	1		1	1			1		3
Glossosomatidae													
Agapetus debilis		1											
Hydropsychidae													
Arctopsyche grandis							3	1					1
Limnephilidae													
Limnephilus sp.	1												
Apatania sp.											1	1	
Neothremma alicia			3				2				1		
Ecclisomyia sp.			1										
Neophylax sp.					2								
Lepidostomatidae													
Lepidostoma sp.	1												
Brachycentridae													
Micrasema sp.					1								
Coleoptera (beetles)													
Elmidae													
Stenelmis sp.		4			7								
Diptera (true flies)													
Blephariceridae													
Philorus sp.											1		
Simuliidae													
Prosimulium sp.											1		
Simulium sp.	7												
Chironomidae								3		3			
Stratiomyidae													
Odontomyia sp.	3												
Pelecypoda (clams)													
Pisidium sp.			2										
TOTAL TAXA:	7	6	4	3	10	2	10	7	9	7	9	5	10
TOTAL:	30	40	12	6	74	21	28	40	34	74	46	15	52

surveyed tributaries. In addition, many stoneflies are classified as shredders and require large amounts of riparian vegetation input for survival. Several of the open meadow tributaries of lower Soda Butte Creek would not satisfy this requirement.

Pebble Creek

Pebble Creek is the major tributary of Soda Butte Creek. This stream arises from the southern slopes of Wolverine and Sunset Peaks and flows for approximately 22.8 km to the confluence with Soda Butte Creek (Figure 20). Previous studies classified Pebble Creek as a high quality trout stream with good habitat (Arnold and Sharpe 1965). Cursory-level surveys were conducted on 27 tributaries to Pebble Creek in 1985 (Jones et al. 1986). Five tributaries were surveyed at the cursory level in 1986. During 1985 and 1986, a reconnaissance-level survey was conducted on six stream reaches in Pebble Creek mainstem.

Physical

The present form of Pebble Creek is the result of glacial scouring of Absaroka volcanic flows (Pierce 1974). Over half of Pebble Creek is contained in a relatively steep valley bordered by Mount Hornaday and Barronette Peak. To the east of Cutoff Mountain, Pebble Creek flows through a wide gently sloping meadow.

Older stands of lodgepole pine (*Pinus contorta*) dominate the riparian zone, although Douglas fir (*Pseudotsuga menziesii*) is the most common riparian species in the region of the confluence. At the higher elevations (> 2,500 m), whitebark pine (*Pinus albicaulis*) constitutes the primary forest type. Sagebrush (*Artemesia* sp.) and various grasses form the riparian community in the upper meadow of Pebble Creek. Bull moose (*Alces alces*) were the most frequently observed ungulate during the survey of Pebble Creek; however, evidence of elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) use was noted.

Pebble Creek was classified as a third order stream throughout all six stream reaches. Gradient was moderately low in all sections (Table 33). Reach 1 contains a small canyon and numerous pools formed by boulders. This section of Pebble Creek had the highest degree of channel stability, as shown by the high bank vegetation stability and the limited amount of streambank alteration (Table 33). Reach 1 is heavily

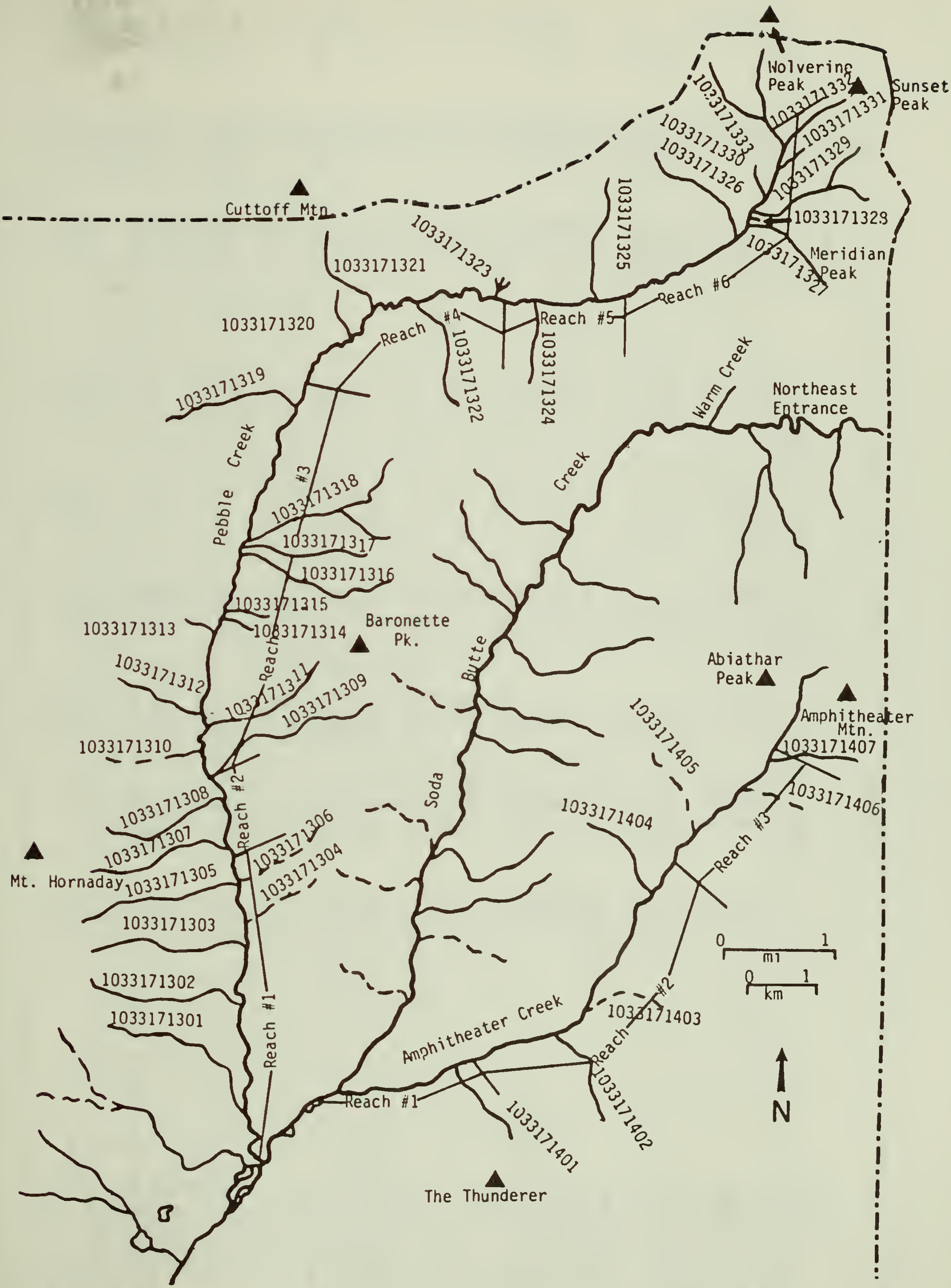

Figure 20. Hydrographic map of Soda Butte, Pebble, and Amphitheater Creeks, 1986.

Table 33 Drainage basin characteristics and habitat features of Pebble Creek and Amphitheater Creek, 1985 and 1986.

	Pebble Creek						Amphitheater Creek		
Habitat Features	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 1	Reach 2	Reach 3
Sample Date	8/6/85	8/7/85	8/8/85	7/16/86	7/16/86	8/9/85	7/31/86	7/15/86	8/10/85
Time	1530	1100	1030	1130	1800	1330	0945	1413	1500
Stream Order	III	III	III	III	III	III	II	II	II
Length (km)	4.60	1.20	6.20	4.40	1.80	3.40	1.90	4.00	2.00
Elevation:									
Maximum (m)	2244.9	2273.8	2374.4	2423.2	2462.8	2589.3	2218.9	2438.4	2548.1
Minimum (m)	2069.6	2244.9	2273.8	2374.4	2423.2	2462.8	2094.0	2218.9	2438.4
Drainage Size (ha)	6290.8	5207.9	4809.2	2730.1	1757.5	1233.8	2394.1	1949.1	878.1
Water Column:									
Flow (m3/s)	0.5426	0.4254	0.3324	0.4404	0.3319	0.103	0.226	0.273	0.095
Channel Width (m)	10.83	12.17	10.25	16.71	23.06	6.51	6.28	10.49	12.91
Stream Width (m)	7.70	8.74	6.77	6.13	6.10	2.99	3.82	4.17	4.00
Stream Depth (cm)	16.15	13.11	10.67	13.72	12.50	10.36	24.99	16.15	9.14
Stream Shore Water Depth (cm)	0.00	3.96	5.49	3.96	0.00	3.96	10.36	14.63	0.91
Riffle Width (m)	5.11	6.06	6.00	4.72	3.01	1.97	0.47	2.50	2.80
Pools:									
Width (m)	2.64	2.69	0.76	1.41	0.75	0.91	3.35	1.67	0.97
Quality	1.69	1.55	1.14	1.33	1.27	1.00	1.31	2.00	1.33
Feature	4	4	1	3	3	3	4	4	3
Solar Angle	58.67	82.67	102.00	122.00	139.70	45.33	17.67	63.00	74.67
Channel Morphology									
Streambank Alteration	15.00	26.67	44.17	21.67	60.00	22.50	9.17	45.80	51.67
Vegetative Stability	3.50	3.17	2.83	2.30	1.50	3.00	3.67	2.50	2.17
Undercut (cm)	0.00	8.53	6.10	0.91	0.00	3.05	67.06	5.18	7.01
Channel-Bank Angle	145.83	126.33	129.17	119.33	139.17	143.33	77.50	118.00	120.00
Stream Bottom:									
Gradient (%)	2.33	1.17	0.67	1.50	3.33	2.33	13.77	5.50	1.67
Sinuosity	1.15	1.08	1.04	1.23	1.10	1.20	1.20	1.14	1.11
Substrate:									
Boulder >356 mm	46.06	25.09				33.06	50.56	34.00	10.79
Cobble 64-356 mm	46.02	58.64	44.58	86.81	97.5	56.77	10.62	66.00	44.61
Gravel 2-64 mm	5.27	12.79	50.92	6.6		10.17	38.82		33.82
Sand 0.6-2 mm					2.5				
Silt <0.6 mm	2.65	3.48	4.49	6.6					10.79
Embeddedness	3.33	2.67	3.67	4.00	4.33	2.67	3.33	4.33	4.33
Channel Vegetative Cover (cm)	0.00	15.24	0.00	0.00	5.18	0.00	0.00	11.28	0.00
Riparian Zone:									
Streamside Cover	2	2	2	4	1	2	1	1	1
Vegetative Use	13.33	7.50	13.33	12.50	15.00	15.83	5.00	12.50	6.67
Vegetation Overhang (cm)	0.00	6.10	8.53	2.44	0.00	7.62	0.00	2.13	1.83
Habitat Type	9,17	9	9,19	8	2,8	15	13	12,18	3,13

shaded by the dense lodgepole pine growth in the riparian zone, but downfall in the channel is at a minimal level.

As the name implies, the stream channel of Pebble Creek is dominated by smaller substrate sizes. With the exception of Reach 1, a minimum of two thirds of the substrate was composed of gravel and cobble in each survey reach (Table 33). Embeddedness was moderate throughout the entire stream (mean rating = 3.5 or approximately 30% embeddedness). High channel bank angles indicate relatively few undercut banks in Pebble Creek. Only Reaches 2 and 3 contained a significant proportion of undercut banks that could provide cover for fish. Meadow sections (Reaches 3 and 4) are lined with overhanging grass that may provide shade and cover for resident fish.

Riffles and shallow runs predominate in Pebble Creek. Pools were small and of fair quality in the middle sections of the stream (Reach 3, 4, and 5). The uppermost survey section (Reach 6) has the appearance of a typical headwater stream. Pool-riffle ratio in Reach 6 approximates 1:1, but the majority of the pools provide only marginal cover.

Throughout its length, Pebble Creek is relatively stable, wide, and shallow. Even in those sections bordered by dense conifer stands, downed timber in the stream channel is minimal. Despite the high width to depth ratios of the stream transects, Pebble Creek appears to contain peak flows, and flood damage is only moderate.

The primary exception to this condition occurred in Reach 5, which has heavily degraded streambanks with very limited stability. Streambank composition is primarily gravel and fine sediments. The high water flood channel in Reach 5 was nearly twice the mean channel width of Pebble Creek (Table 33). Substrate in Reach 5 was almost entirely composed of loose cobble, and embeddedness in this section was the lowest of any stream reach in Pebble Creek. The tendency of this loose substrate to be displaced during high streamflows is enhanced by the higher than average gradient occurring in this stream reach (Table 33).

Four of the five first order tributaries to Pebble Creek surveyed in 1986 are short (mean length = 1.5 km), high gradient streams (Table 31), but stream 1033171328 arises from a cold spring and flows at a moderate gradient (8.6%) for approximately 0.4 km before joining Pebble Creek. All five tributaries had mean depths less than 10 cm and streamflows less than 0.04 m^3/s. Tributary 1033171326 had the lowest streamflow and highest water temperature (Table 31). This stream originates on a south facing slope (Figure 20) and may become intermittent in years of low precipitation.

Biological

Macroinvertebrates

In 1985, macroinvertebrate samples were collected from 4 stream reaches and 12 tributaries to Pebble Creek. Additional samples from two stream reaches and five tributaries were collected in 1986. The following discussion relates to macroinvertebrate samples from both field seasons.

Mean mainstem macroinvertebrate diversity in Pebble Creek was higher than that from tributaries to lower Soda Butte Creek but slightly lower than mean diversity in Amphitheater Creek (Tables 32 and 34). Ephemeropterans and Trichopterans were well represented in all stream reaches except Reach 2 (Table 34). Heptageniid mayflies exhibited the highest family density throughout Pebble Creek drainage.

Plecopterans were found in minimal numbers in the mainstem of Pebble Creek. *Zapada* sp. is primarily a detritivore (Merritt and Cummins 1978), relying on input from riparian sources. The open meadow areas and lack of downed timber in Pebble Creek are not conducive to high densities for this species.

Tributaries to Pebble Creek are less productive than the mainstem, as suggested by lower macroinvertebrate density and species diversity (Table 34). Although stream 1033171328 had the highest density of macroinvertebrates of any sample in the Soda Butte Creek drainage, this stream is an exception to the norm in Pebble Creek drainage. Of all macroinvertebrate samples in Pebble Creek, only tributary 1033171328 yielded any significant representation of Dipterans.

Aquatic Vertebrates

During the 1985 stream surveys, Reach 6 and tributaries 1033171320, 1033171323, and 1033171329 were sampled for cutthroat trout (*Salmo clarki*). Numbers of captured trout were 19, 12, 6, and 3, respectively. Only

Table 34. Occurrence and densities of macroinvertebrates found in stream reaches and tributaries of Pebble Creek, 1985 and 1986.

	Reach No.						Tributary #10331713									
	01	02	03	04	05	06	06	07	17	21	24	25	26	27	28	32
Turbellaria							2		1	2						
Insecta																
Ephemeroptera (mayflies)																
Siphlonuridae																
Ameletus sp.							1		1						1	
Baetidae																
Baetis bicaudatus	5		2	1	3	8			8	4	5	4		2	5	
Heptageniidae																
Cinygmula sp.	4		3	9	27	16					10	5	12	4	5	
Epeorus longimanus			2													
Epeorus deceptivus	13	1	3			7				1						
Emphemerellidae																
Drunella coloradensis	3	2	3	1		1			1			1				
Drunella doddsi	2		2													
Seratella mitchneri	9		7													
Plecoptera (stoneflies)																
Peltoperlidae																
Yoroperla brevis												3			16	1
Nemouridae																
Zapada sp.	4		1			8		6							8	3
Visoka cataractae								1								
Capniidae																
Isocapnia sp.										1						
Perlodidae																
Megarcys sp.							1									12
Isoperla sobria										1					1	
Isoperla perersoni										2						
Chloroperlidae	1														3	
Perlidae																
Doroneuria theodora								1								
Trichoptera (caddisflies)																
Rhyacophilidae																
Rhyacophila sp.	4				2	4	3		4		2				1	2
Glossosomatidae																
Glossosoma sp.	1		7			2										
Hydropsychidae																
Arctopsyche grandis	7		1			3		4								
Limnephilidae																
Apatania sp.				1	20	14										11
Lepidoptera (moths)											1					
Coleoptera (beetles)																
Elmidae																
Stenelmis sp.									1							
Diptera (true flies)																
Tipulidae																
Dicranota sp.															1	
Simuliidae																
Prosimulium sp.															3	
Chironomidae									4					3	32	3
Ephydridae						1							1			
TOTAL TAXA:	11	2	10	4	4	10	4	4	8	7	4	4	1	2	11	6
TOTAL:	53	3	31	12	52	64	7	12	30	16	20	12	1	5	76	32

juvenile fish were collected in tributary 1033171320, which has a small streamflow and a densely vegetated stream channel. The largest cutthroat trout (TL=349 mm) was collected in Pebble Creek mainstem. Similarly sized trout were collected in Reach 6 and streams 1033171328 and 1033171329.

Angler Use

Pebble Creek supports a relatively popular cutthroat trout fishery. Mean annual angler effort since 1974 has been approximately 1,250 hours. However, effort has declined dramatically in the past 2 years, and angler effort in 1986 (613 hours) was the lowest in the past 12 years (Figure 21). Although there was a slight increase in landing rate from 1985 to 1986 (1.45 and 1.65 fish/hr, respectively), the landing rate is still below the 12-year average (1.83 fish/hr). Numbers of creeled fish parallel fishing effort (Figure 21). The estimated creel for 1986 was the lowest in 12 years. Mean length of landed trout has fluctuated somewhat since 1980. While current estimates are at the lower extreme of the observed range, there is no evidence of a significant decline in average size in the past 12 years. Mean length of creeled fish in 1986 was 259 mm and 5% were longer than 330 mm. Since anglers have a tendency to creel older and larger trout, evidence suggests that angler harvest may be depressing the mean length of cutthroat trout. While implementation of a 330 mm minimum size limit in 1987 should provide protection to younger and smaller trout, continued harvest of the oldest and largest fish can be expected.

Amphitheater Creek

Amphitheater Creek, a major tributary of Soda Butte Creek, is enclosed in a narrow valley surrounded by Abiathar Peak, Amphitheater Mountain, and The Thunderer (Figure 20). Arnold and Sharpe (1965) reported that Amphitheater Creek had only limited fisheries potential. In 1981, streamflow, pH, and water temperature were recorded at the mouth of Amphitheater Creek (Jones et al. 1982). During 1985 and 1986, a reconnaissance survey was conducted on three sections of Amphitheater Creek and a cursory survey was performed on seven tributaries to Amphitheater Creek.

Physical

The valley floor of Amphitheater Creek is covered with glacial till overlying Absaroka andesitic flows. Due to these resistant materials, only minor amounts of

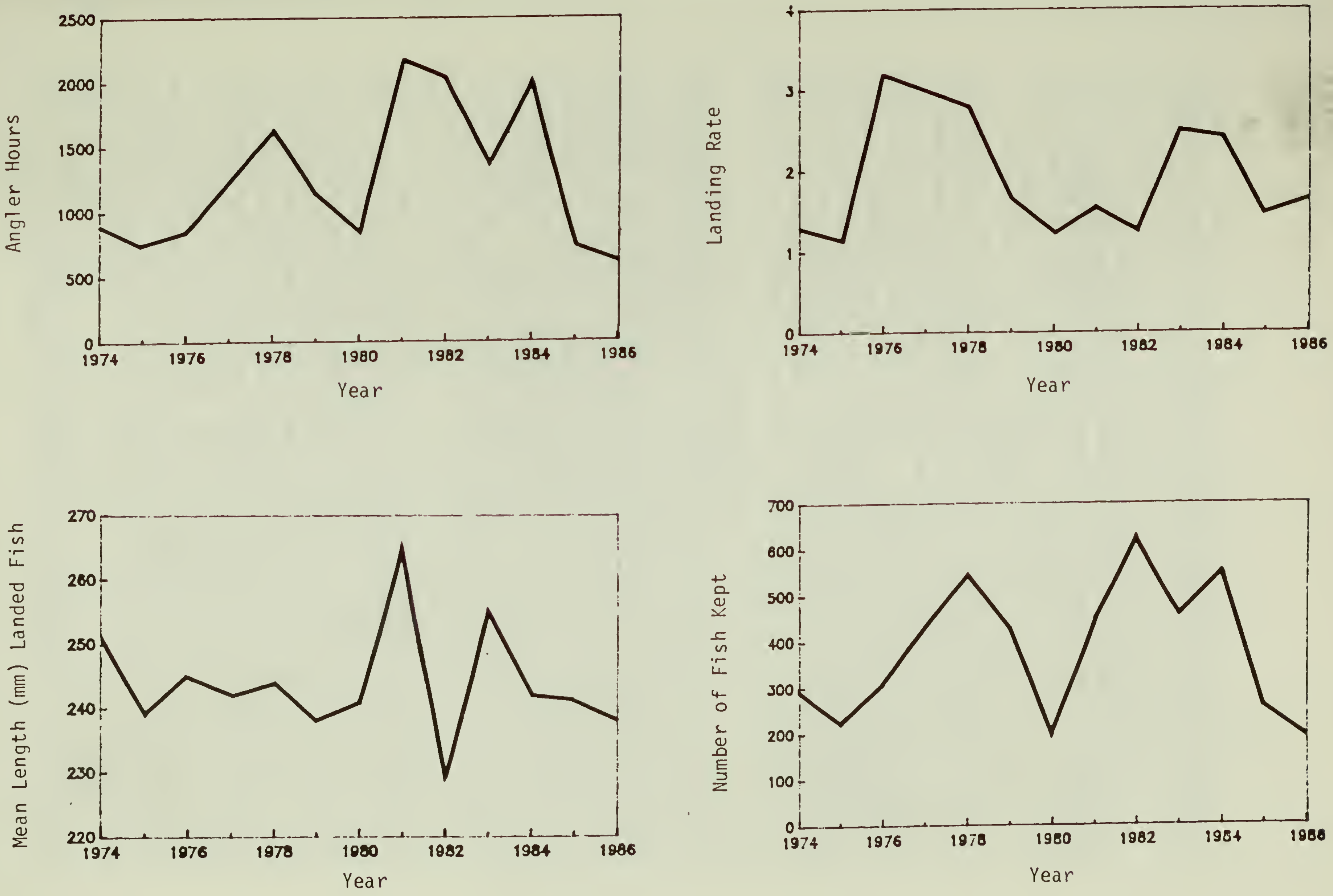

Figure 21. Angler statistics for Pebble Creek, 1974-86.

chemical constituents should be found in waters draining this geologic type (Meyer in press).

The lower portion of Amphitheater Creek (Reach 1) (Figure 20) is located in a Douglas fir (*Pseudotsuga menziesii*) and Engelmann spruce (*Picea engelmanni*) riparian zone. Although the upper sections of the stream are heavily forested, there are large meadows at the base of Amphitheater Mountain. North and west facing slopes at the base of The Thunderer are vegetated primarily by lodgepole pine (*Pinus contorta*), while the slopes on the opposite side of Amphitheater Creek are covered predominantly by a Douglas fir-whitebark pine (*Pinus albicaulis*) complex. Although elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), and moose (*Alces alces*) inhabit the drainage, the dominant ungulate is bighorn sheep (*Ovis canadensis*). Well developed game trails provide the main access in the lower section of the stream (Reaches 1 and 2).

Reach 1 is bordered by a high gradient canyon and contains a long series of steep cascades downstream from tributary 1033171401 (Figure 20). The very low solar angle in this reach (Table 33) is a reflection of the nearly constant shading of the stream channel by thick riparian cover. Numerous pools formed by boulders occur much more frequently than small riffle areas. Bedrock and large boulders are the dominant substrate in this stream reach. The narrow, deep channel, in conjunction with the high degree of vegetative stability, appears to contain peak flows and streambank alteration is minimal (Table 33). One unidentified trout (TL ≈ 150 mm) was observed in this stream reach.

Stream Reaches 2 and 3 were characterized by low gradients, numerous log debris jams, few pools, and shallow, wide stream channels (Table 33). Undercut banks were rare and substrate was dominated by sizes less than 356 mm in diameter. High water flood damage and streambank alteration increases in an upstream direction in Amphitheater Creek. Several exposed slopes exhibit a high potential for mass wasting in the upper portion of Reach 2 and the lower portion of Reach 3 (Figure 20). Instream cover for fish in the upstream half of Amphitheater Creek is restricted primarily to downed timber and pools of only fair quality. Although Reach 3 was sampled for fish, none were captured or observed.

Of the seven tributaries surveyed, only streams 1033171401, 1033171402, and 1033171403 are perennial streams (Table 21). These three cold water streams originate on the north side of The Thunderer, and flow slightly over 1 km to Amphitheater Creek. These streams are steep (mean gradient = 23.9%), but all are heavily vegetated with mosses, possibly due to groundwater inflow. Four intermittent runoff channels appear to contribute significant amounts of sediment and debris to Amphitheater Creek mainstem during peak flows.

Chemical

The resistant andesitic geology of the Amphitheater Creek drainage basin was reflected in the water chemistry. Amphitheater Creek (TDS = 32 mg/l) was classified as a dilute stream (TDS < 50 mg/l). With the exception of silica, this magnesium bicarbonate stream exhibits less than the parkwide mean for nearly every chemical constituent analyzed (Table 35). Consequently, only limited biological production could be expected in Amphitheater Creek.

Biological

Macroinvertebrates

Although Amphitheater Creek is a dilute water, benthic macroinvertebrate diversity and density in Amphitheater Creek was slightly higher than that observed in unnamed Soda Butte Creek tributaries (Table 32). Although Ephemeropterans and Plecopterans are well represented, Trichopteran density and diversity is quite low in the Amphitheater Creek drainage. This distribution contrasts markedly with Arnold and Sharpe (1965). They found that the dominant invertebrate throughout Amphitheater Creek was a large case building caddisfly approximately 20 mm long. *Arctopsyche grandis* fits this description. However, in 1986, *Arctopsyche* and other Trichopterans were restricted to the most stable portions of the drainage (tributaries and Reach 1). Although environmental tolerances are similar for Trichopteran and Plecopteran species collected in Amphitheater Creek, the low embeddedness and high channel instability in the upper two survey reaches may limit caddisfly survival or keep density low enough that Trichopterans may not be represented in the macroinvertebrate samples. Since Plecopterans are more mobile and active than the Trichopterans, the stoneflies may be better able to adjust to a shifting substrate during peak flows. In addition, all of the Plecopteran species collected in Amphitheater Creek are predatory, and the Trichopteran distribution may reflect a response to heavy predation.

Table 35. Chemical characteristics of backcountry streams surveyed, Soda Butte Creek and Heart Lake drainages, Yellowstone National Park, 1986.

	Upper Soda Butte Creek	Confluence of Soda Butte Creek with Warm Creek	Lower Soda Butte Creek	Confluence of Soda Butte Creek with Lamar River	Amphitheater Creek	Warm Creek	Heart Lake Tributary 302308
Water Temperature (C)	8	11	10	11	8	8	13.9
Spec. Cond (µmhos)	165	190	220	230	73	265	-
pH	7.5	8.1	7.4	7.5	7.2	8.3	-
Total Alkalinity	93.0	101	135	129	43.0	145	4.1
Ca Hardness	62.40	71.61	78.86	83.47	14.73	103	7.54
Total Hardness	88.55	104	123	130	30.17	159	<11.7
Total Dissolved Solids	105	120	150	145	32	175	15.0
Carbonate Alkalinity	0	0	0	0	0	0	0
Bicarbonate Alkalinity	93.0	101	135	129	43.0	145	4.1
Carbonates	0	0	0	0	0	0	0
Bicarbonates	114	123	165	157	52.5	177	5.0
Hydroxides	0	0	0	0	0	0	0
Carbon dioxide	1.9	1.3	21.0	2.6	1.4	1.5	2.8
Chloride	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Sulfate	19.4	20.8	20.1	19.1	2.1	24.8	1.8
Fluoride	0.045	0.051	0.072	<0.069	0.044	0.073	0.581
Potassium	<1.0	<1.0	1.0	2.0	2.0	<1.0	<1.0
Mg Hardness	26.15	31.96	44.27	46.78	15.44	55.96	<4.12
Calcium	24.99	28.68	31.58	33.43	5.90	41.26	3.02
Magnesium	6.35	7.76	10.75	11.36	3.75	13.59	<1.00
Sodium	5.0	5.0	5.0	5.0	4.0	4.0	2.88
Iron	0.47	0.39	0.23	0.22	0.10	<0.10	0.24
Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica	6.0	7.2	8.9	9.1	15.3	5.9	6.6
Color (PCU)	0	0	5	0	0	0	20
Turbidity (NTU)	0.4	0.6	1.0	0.2	0.3	0.1	0.3
TOC	23.0	8.2	2.2	12.5	2.0	9.9	6.04
Ortho-phosphate	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.03

Dipterans were represented in both stable and unstable sections of Amphitheater Creek by Chironomids and Simulids (Prosimulium sp.). These species are classified as very tolerant of environmental fluctuations (Winget and Mangum 1981). In contrast, Philorus sp. (Blephaceridae), collected in stream 1033171401, was the most environmentally sensitive macroinvertebrate sampled during the 1986 stream surveys. Blephaceridae require a cool, oxygen-rich water with high velocity. The ventral suckers of the larvae are an adaptation to small turbulent mountain streams.

Aquatic Vertebrates

Historically, Amphitheater Creek has been described as containing a cutthroat trout (Salmo clarki) population. In 1938 and 1939, nearly 100,000 cutthroat trout (Salmo clarki) fry were stocked in Amphitheater Creek (Varley 1981). Arnold and Sharpe (1965) found fish only in the lower 0.4 km of Amphitheater Creek. Only one fish was observed during the 1986 survey, near the upper end of the canyon in Reach 1. While the presence of this fish demonstrates that the cascades are not a total barrier to fish movement, the cascades may be a major factor limiting a sizeable population in Amphitheater Creek. Whether fish observed in lower Amphitheater Creek are migrants from Soda Butte Creek or descended from stocked fish is unknown.

Angler Use

Current estimates of angler use indicate that fishing effort on Amphitheater Creek is extremely light. Less than 15 days/year are spent fishing, and the majority of the effort is almost certainly concentrated near the confluence with Soda Butte Creek. Although game trails parallel the stream drainage, steep canyons and downed timber in the stream channel make access extremely difficult. Although new angling regulations in 1987 may provide protection to fish stocks in Amphitheater Creek, the effects may be minimal since angler impacts appear to be negligible.

SLOUGH CREEK WATERSHED

Slough Creek is one of the most popular recreation areas in the northeast section of Yellowstone National Park (YNP). The wide, gently sloping Slough Creek valley presents a sharp contrast to the narrow, steep tributaries surveyed in 1985 and 1986. Middle Pinedale and gravel alluvium in the present Slough Creek flood plain, while the major tributaries are overlain with glacial till (Pierce 1974).

Buffalo Creek

Buffalo Creek originates in the Gallatin National Forest and enters Yellowstone National Park (YNP) as a fourth order stream. This major tributary of Slough Creek flows nearly 11 km through a narrow V-shaped valley of glacial till underlain by Precambrian gneiss. Canyons with vertical walls, large bedrock outcroppings, and a landslide deposit in the middle section of the watershed characterize the primary geological features of Buffalo Creek.

Prior to 1985, surveys of Buffalo Creek were very limited. Arnold and Sharpe (1967) described the 0.8 km of Buffalo Creek upstream from the confluence with Slough Creek as severely impacted by high water, but they collected several cutthroat trout and rainbow trout under 254 mm. In 1985, a reconnaissance-level survey was conducted on three stream reaches of Buffalo Creek. Results from a cursory-level survey of seven tributaries to Buffalo Creek in 1985 are summarized in Jones et al. (1986). Due to time constraints, a planned reconnaissance survey of Reach 4 in 1986 was not accomplished.

Physical

From the confluence with Slough Creek upstream to stream 1033020305 (Figure 22), the Buffalo Creek watershed is forested primarily by Douglas fir (Pseudotsuga menziesii). Older growth lodgepole pine (Pinus contorta) dominates the upper reaches of the stream. Although Buffalo Creek is typified by rugged terrain, evidence of ungulate use was noted throughout all survey reaches, and grizzly bear (Ursus arctos horribilis) activity was noted in the Reach 3. Reach 3 contained short canyons (< 1 km in length) which were not surveyed due to their inaccessibility. Each canyon was bordered by a high vertical wall (8-23 m) on one or both sides of the stream. The upper end of each canyon contained a waterfall or steep cascades ranging from 7 to 15 m high. A primary habitat feature noted in each canyon was the excellent Class V pools. These pools were several meters deep and some approached 30 m in length.

All three survey reaches were low gradient and exhibited only moderate amounts of streambank alteration

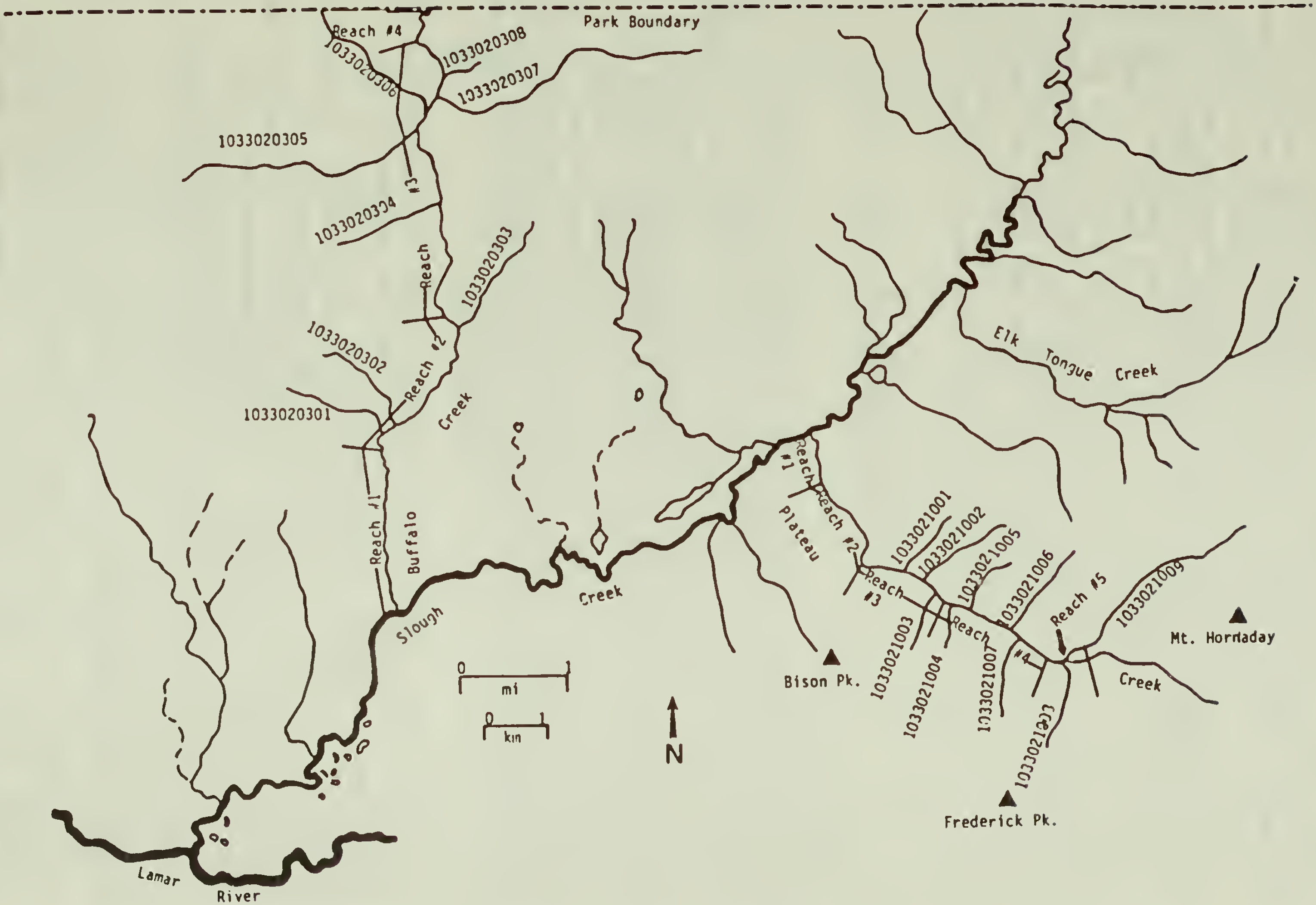

Figure 22. Hydrographic map of Slough, Buffalo, and Plateau Creeks, 1986.

(Table 36). Streambanks were nearly vertical and appear to contain peak flows. Vegetation stability and riparian condition were rated good in all three survey sections. Significant amounts of instream vegetation, primarily large patches of freshwater mosses, were noted in each stream reach. Reach 1 contained numerous high quality pools, and substrate was almost entirely boulder and bedrock (Table 36). In Reach 2 and Reach 3, there was a shift to a greater percentage of cobble in the substrate composition and a change in pool:riffle ratio to reflect a dominance of riffles. The reconnaissance survey indicated high quality fisheries habitat in all sections of Buffalo Creek; however, minimal amounts of gravel in the substrate may affect potential spawning in this stream.

Biological

Macroinvertebrates

Macroinvertebrate collections from Buffalo Creek mainstem exhibited relatively high density of individuals and low species diversity (Table 37). Four orders were collected: Ephemeroptera, Trichoptera, Coleoptera, and Diptera. Epeorus deceptivus was the most frequently collected species in Buffalo Creek. According to Cummins (1977), a fourth order stream should be dominated by collectors and detrivores utilizing autochthonous production, while scrapers and predators comprise a minority of species diversity. The percentages of these functional groups in Buffalo Creek were 75.0, 8.3, and 16.7, respectively.

In first order tributary streams, riparian input has a greater influence on macroinvertebrate populations. Most Plecopterans are dependent on this riparian detritus. Although Plecopterans were totally absent from Buffalo Creek mainstem, they constituted a significant portion of the macroinvertebrate populations in the tributary streams. Ephemeropterans were the dominant group, in terms of density and species diversity, in each tributary except stream 1033020303 (Table 37).

Aquatic Vertebrates

Historically, Buffalo Creek was barren of fish life (Varley 1981). In 1932, the state of Montana stocked rainbow trout (Salmo gairdneri) in Hidden Lake, which is located on a tributary to Buffalo Creek outside YNP. An additional plant of Yellowstone cutthroat trout

Table 36. Habitat characteristics of Plateau Creek and Buffalo Creek, 1985-86.

Habitat Features	Plateau Creek Reach 2	Plateau Creek Reach 3	Plateau Creek Reach 4	Plateau Creek Reach 5	Buffalo Creek Reach 1	Buffalo Creek Reach 2	Buffalo Creek Reach 3
Sample Date	7/24/86	7/23/86	7/23/86	7/23/86	8/11/85	8/12/85	8/13/85
Time	1200	1700	1230	1545	1200	1030	1500
Stream Order	II	II	II	I-II	IV	IV	IV
Length (km)	1.6	1.4	1.8	0.6	1.6	3.7	4.6
Elevation:							
Maximum (m)	2170.2	2267.7	2365.2	2439.9	1987.3	2121.4	2269.2
Minimum (m)	2022.3	2170.2	2267.7	2365.2	1900.0	1987.3	2121.4
Drainage Size (ha)	2169.6	2008.2	1642.0	1201.0	4036.2	3914.1	2465.0
Water Column:							
Flow (m3/s)	0.245	0.164	0.210	0.208	0.810	0.660	0.956
Channel Width (m)	10.8	8.4	9.0	6.4	17.5	19.2	20.0
Stream Width (m)	5.9	6.0	4.2	3.0	13.8	12.9	16.9
Stream Depth (cm)	15.24	15.24	15.24	12.19	28.96	22.86	14.33
Stream Shore Water Depth (cm)	3.05	6.10	3.05	3.05	3.05	0.00	0.00
Riffle Width (m)	1.58	1.77	0.82	0.85	4.23	8.85	13.05
Pools:							
Width (m)	1.5	1.6	3.4	1.0	9.4	6.0	3.9
Quality	1.2	2.0	1.7	1.6	3.0	1.6	1.8
Feature	3.8	3.9	3.9	3.9	4.6	3.1	4.0
Solar Angle	50.0	44.0	34.3	33.7	47.0	64.3	59.7
Channel Morphology							
Streambank Alteration	24.2	28.3	23.2	27.5	23.0	22.5	31.7
Vegetative Stability	3.3	3.5	3.5	3.8	3.2	3.0	3.0
Undercut (cm)	12.2	9.1	3.0	9.1	20.4	0.0	162.2
Channel-Bank Angle	107.3	128.2	131.7	139.2	118.8	128.8	113.5
Stream Bottom:							
Gradient (%)	9.6	7.3	6.3	5.7	3.5	1.2	1.2
Sinuosity	1.30	1.20	1.10	1.30	1.17	1.07	1.09
Substrate:							
Boulder >356 mm	35.7	8.6	27.2	23.2	94.1	36.6	54.4
Cobble 64-356 mm	55.3	65.8	26.1	60.2	3.7	61.8	40.8
Gravel 2-64 mm	5.4	17.1	38.3	16.6			1.2
Sand 0.6-2 mm		5.1				0.8	3.6
Silt <0.6 mm	3.6	3.4	8.4		2.2	0.8	
Embeddedness	3.33	4.00	4.00	3.30	4.00	2.73	4.00
Channel Vegetative Cover (cm)	0.00	6.10	0.00	3.05	55.78	40.54	25.30
Riparian Zone:							
Streamside Cover	2.5	1.8	1.8	2.3	1.0	2.0	2.0
Vegetative Use	14.20	12.50	12.50	8.30	3.33	12.50	16.25
Vegetation Overhang (cm)	18.29	9.14	67.06	30.48	0.00	3.05	7.32
Habitat Type	9,13	9,13	12,13	8,9	12	12	12,15

Table 37. Occurrence and densities of macroinvertebrates found in reaches and tributaries, Plateau & Buffalo Creeks, 1985-1986.

	Plateau Creek									Buffalo Creek							
	Reach No.			Tributary: 10330210						Reach No.			Tributary: 10330203				
	02	03	05	04	05	06	07	08	09	01	02	03	01	03	05	06	07
Turbellaria (planarians)				4	2	5			1				2			2	
Insecta																	
Ephemeroptera (mayflies)																	
Siphlonuridae																	
Ameletus sp.		1		8			3	1				1					
Baetidae																	
Baetis bicaudatus		3	7		4	9	1	28	8			2		7	5		6
Baetis tricaudatus										12	17					3	
Heptageniidae																	
Cinygmula sp.	1	3	2				2	15					1		1	9	5
Rithrogena sp.					9				2								
Epeorus grandis										1							
Epeorus deceptivus			2			4			4	7	20	23					17
Ephemerellidae																	
Drunella coloradensis													2				
Seratella mitchneri											3	7				9	
Plecoptera (stoneflies)																	
Peltoperlidae																	
Yoraperla brevis			2	6	1		2	9	1								
Nemouridae																	
Amphinemoura sp.			2														
Zapada sp.							18			12		1		6	2	2	4
Visoka cataractae							19			3							
Capniidae																	
Isocapnia sp.				1													
Perlodidae																	
Megarcys sp.		1															
Isoperla sobria								2									
Isoperla sp.							1							1			
Chloroperlidae				2			1	1	1								2
Perlidae																	
Doroneuria theodora	1														3		
Trichoptera (caddisflies)																	
Rhyacophilidae																	
Rhyacophila sp.									2	6		2	1		3	4	1
Glossosomatidae																	
Anagapetus sp.			1														
Hydropsychidae																	
Arctopsyche grandis											1						1
Parapsyche elsis										1	1						
Parapsyche sp.			4														
Limnephilidae																	
Neothremma alicia		3	1	6	2	48											4
Homophylax sp.								1									
Cryptochila furcata				1													
Imania sp.				7													
Coleoptera																	
Elmidae																	
Cleptelmis sp.										1	1				2		
Diptera (true flies)																	
Tipulidae																	
Hexatoma sp.						1					9						
Tipula sp.																	
Simuliidae																	
Prosimulium sp.				4				1			9						
Chironomidae	1						6	1						6	4		
TOTAL TAXA:	3	5	8	11	5	6	8	10	7	6	8	5	4	4	7	6	8
TOTAL:	3	11	21	76	18	79	19	60	19	28	61	37	6	20	20	29	40

(Salmo clarki) was made in the Gallatin National Forest in the early 1940's (C. Clancy, personal communication, March 1987). Because the waterfalls in Buffalo Creek function as permanent barriers to upstream fish passage, present trout distribution is dependent on downstream migration from previously stocked fish and natural recruitment.

During reconnaissance surveys, trout were observed in Reaches 1, 3, and 4. Visual estimates of trout length in the large canyon pools were 450 mm to 500 mm. Due to the large size of Buffalo Creek, the mainstem could not be effectively sampled for fish with rotenone; however, four tributaries were sampled. Stream 1033020302 yielded 11 cutthroat trout with a mean length of 77 mm (range: 22-137 mm). Six trout fry (length ≈ 25-50 mm) were captured in stream 1033020303. In tributary 1033020306, 15 juvenile cutthroat trout were collected (mean length = 72 mm). Possibly as a result of a very steep initial gradient, no fish were collected in stream 1033020307. Thus, it appears that at least three tributaries to Buffalo Creek are being utilized by spawners.

Angler Use

Fishing pressure in Buffalo Creek is probably minimal. Current angler estimates yielded 15 angler days/year. Because access throughout Buffalo Creek is quite limited, the majority of fishing effort is most likely concentrated in the vicinity of the confluence with Slough Creek. Two anglers were observed landing three trout in this lower reach during the stream survey. Reported mean length of landed fish in 1986 was 178 mm.

The high quality habitat throughout Buffalo Creek and visual observations of trout both indicate a potentially significant resident trout population. Limited access has kept angler impact in Buffalo Creek at a minimal level. Consequently, downstream trout migration from the lower section of this stream may contribute substantially to the heavily used Slough Creek fishery.

Plateau Creek

During the 1985 and 1986 field seasons, a reconnaissance-level survey was conducted on four reaches of Plateau Creek from Slough Creek trail and campsites to a point approximately 5.4 km upstream. Due to time constraints, the lower stream section (Reach 1) from Slough Creek trail to the confluence was not surveyed (Figure 22). The upper boundary of Reach 5 was delineated by a waterfall approximately 10 m high. Because this waterfall is a permanent barrier to fish passage, Plateau Creek was not surveyed above this point. A cursory-level survey was conducted on nine tributaries to Plateau Creek.

Physical

Plateau Creek is a second order stream that originates on the western slope of Mount Hornaday; however, the majority of Plateau Creek borders the northern sides of Frederick Peak and Bison Peak (Figure 22). A dense lodgepole pine (Pinus contorta) forest covers these northern slopes, while the south facing slopes on Plateau Creek are primarily forested by Douglas fir (Pseudotsuga menziesii) stands. Aspect and soil moisture content may be limiting in regards to distribution of these different forest types (Steele et al. 1983).

Each of the four surveyed stream reaches was characterized by a moderate gradient (mean = 7.2%), a heavily forested riparian corridor, and significant amounts of vegetation overhanging the stream surface (Table 36). Reaches were separated primarily on the basis of different substrate compositions, although each reach contained over 50% cobble and boulder. Vegetative stability ratings and streambank alteration in Plateau Creek were among the highest and lowest, respectively, of any stream surveyed in the entire Lamar River drainage. These field measurements indicate that Plateau Creek is one of the most stable streams in this area of the park, and consequently, Plateau Creek maintains a high degree of resistance to high water erosion. Downed timber is scattered throughout the stream but does not occur in significant amounts, except in Reach 2. With the exception of the waterfall, there were no stream features that appeared to be barriers to upstream fish passage. Although pools far outnumber riffles in each stream reach, the majority of pools provide only moderate amounts of cover for fish due to shallow depth (< 0.6 m mean depth). Although Reach 2 contained the highest percentage of boulders in the stream channel, Reach 4 had several longer and deeper pools (Table 36). Undercut banks were infrequent throughout Plateau Creek. As a result, instream cover for fish is restricted primarily to overhanging vegetation and the deepest pools.

All nine surveyed tributaries to Plateau Creek were first order, high gradient streams (Table 31). Tributary 1033021009 had the longest stream length, largest drainage basin, and greatest stream width and mean depth of any tributary (Table 31). Discharge in this stream was twice that of any other tributary and represented over 50% of the upper Plateau Creek streamflow. The upper two streams (1033021008 and 1033021009) also had the highest water temperature. Intermittent tributaries of Plateau Creek are located in the downstream portions of the stream. A large landslide deposit which underlies Reach 2 and Reach 3 (Figure 22) may exhibit increased porosity and contribute to drying out of tributary stream channels in these lower reaches.

Chemical

Extensive water chemistry analyses were not performed on Plateau Creek; however, field measurements yielded an mean pH of 7.2, mean conductivity of 71 umhos, and an average water temperature of 9 C. These values are somewhat below the mean values for the park (Table 25) and may indicate decreased productivity in this stream.

Biological

Macroinvertebrates

Both density and diversity of macroinvertebrates were low in the mainstem reaches of Plateau Creek (Table 37). Ephemeropterans and Trichopterans showed similar distribution patterns; however, Plecopterans were collected only infrequently and Dipterans were represented by a single Chironomid. Baetis bicaudatus was the most frequently collected mainstem species.

In contrast to the mainstem, tributary samples revealed moderate diversity and high macroinvertebrate density. Planarians, Ephemeropterans, and Plecopterans dominated all tributary samples except stream 1033021006 (Table 37). Although the density of Neothremma alicia in tributary 1033021006 was the highest of any species in the Plateau Creek watershed, Trichopteran diversity was a small percentage of species composition in all samples. This shift in species composition from mainstem to tributaries may be a function of nutrient requirements. A large majority of the Trichopterans and Plecopterans collected in Plateau Creek are classified as shredders (Merritt and Cummins 1981) and depend on coarse riparian material for food. Although some downed timber is found in Plateau Creek, the excellent channel stability and streamside vegetation stability may limit riparian input to the mainstem. In contrast, highly vegetated, small tributary streams may provide a better niche for both Trichopterans and Plecopterans. Dipteran species diversity and density in the tributaries was higher than that observed in the mainstem, but was still in the minority.

Aquatic Vertebrates

In 1986, no fish were observed or captured in the survey area (Reaches 2 through 5); however, there are no apparent barriers to fish migration in Reach 1. Since fish have been found in Reach 1 (Arnold and Sharpe 1967), the factors underlying the apparent absence of fish in Reaches 2 through 5 are unknown. Although the gradient in Reach 2 is moderately high, the gradient may not be a permanent barrier. Additional sampling and chemical analyses may provide plausible explanations for the apparent absence of fish in the upper reaches of Plateau Creek.

YELLOWSTONE RIVER TRIBUTARIES

The lower Grand Canyon of the Yellowstone River contains only a limited number of tributary streams. The steep walled canyon is the result of Washburn volcanic flows overlaid by Lava Creek tuff. The top section of Specimen Ridge is covered with large amounts of glacial till.

Quartz Creek and Agate Creek flow west off Specimen Ridge and drop through steep unconsolidated landslide deposits into the Yellowstone River (Figure 23). The canyon areas and some upper reaches are forested primarily by Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*); however, the top of Specimen Ridge is primarily open sagebrush (*Artemisia* sp.) meadows.

Quartz Creek

Physical

Quartz Creek was divided into three sections for reconnaissance surveys; however, only Reach 2 was surveyed. The upper section of Quartz Creek (Reach 3) is subject to radical flow fluctuations. This reach is enclosed in a large sagebrush (*Artemisia* sp.) meadow. Flow was detectable in the morning hours, but the

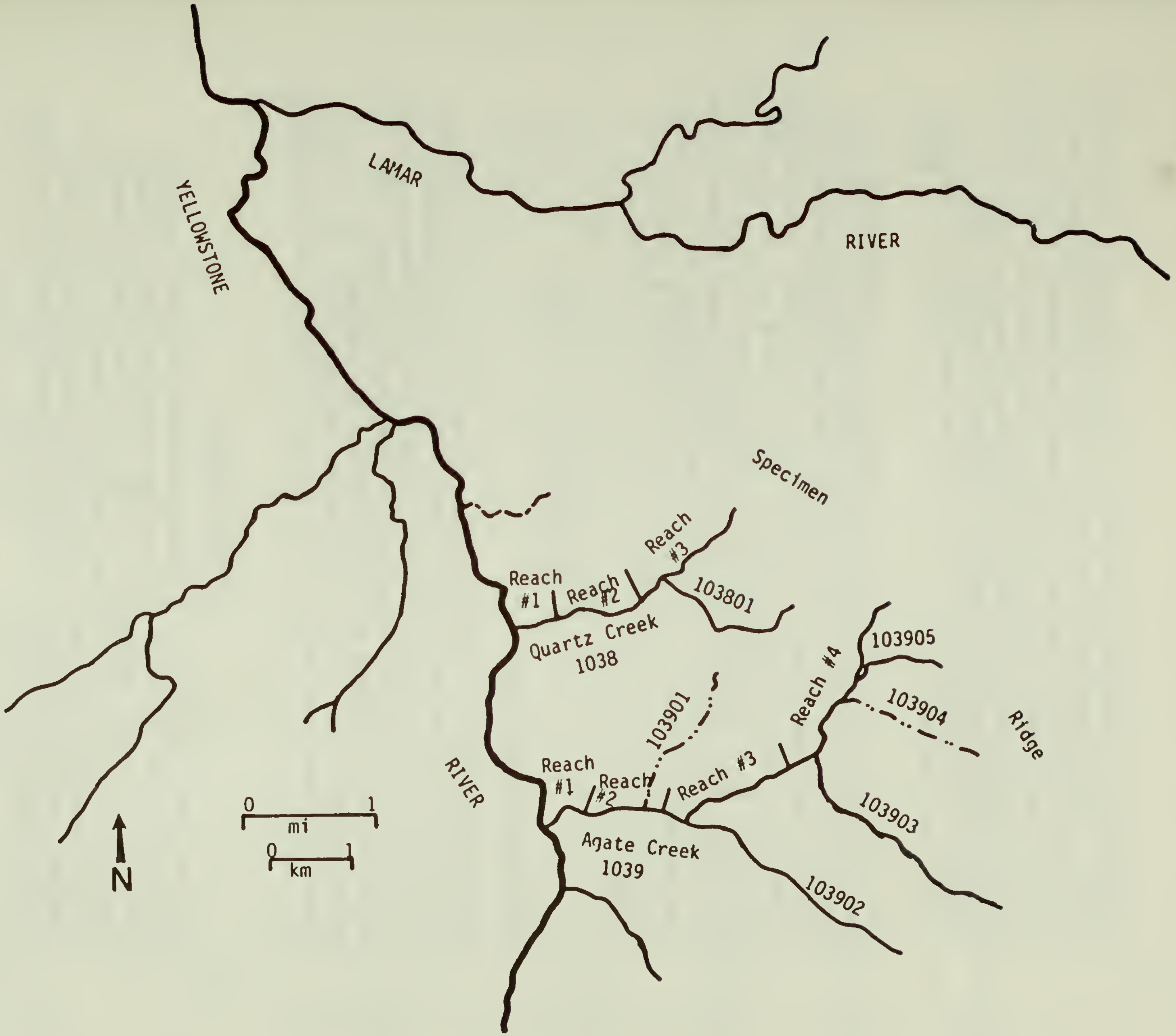

Figure 23. Hydrographic map of Quartz and Agate Creeks, 1986.

grass-filled channel was dry in the afternoon on 19 July 1985. High gradient, extremely low embeddedness, and a heavily impacted channel characterize Reach 2 (Table 38). The steep cliffs bordering this section of Quartz Creek have a high potential for mass wasting and significant sediment input. Numerous small, poor quality pools dominate this stream reach, and instream cover is limited.

The lowest reach of Quartz Creek has a lower gradient and a more stable configuration than Reach 2. Because Quartz Creek sinks into glacial deposits approximately 100 m upstream from the confluence with the Yellowstone River, a reconnaissance-level survey was not conducted on Reach 1. It appears that Quartz Creek flows directly into the Yellowstone River only during peak flows. Due to the degraded condition of the perennial section of the stream (Reach 2), Quartz Creek exhibits only marginal habitat and offers little or no fisheries potential.

Biological

Macroinvertebrates

Macroinvertebrate density and diversity in Quartz Creek were both moderately high (Table 39). High numbers of Trichopterans were associated with the filamentous algae found in the stream channel. Dominance of the invertebrate sample by Trichopterans instead of Ephemeropterans is the exception rather than the norm in lower Yellowstone River tributaries (Table 39) (Jones et al. 1986).

Agate Creek

During 1985 and 1986, a reconnaissance-level survey was conducted on four stream reaches in Agate Creek (Figure 23). In addition, five tributaries to Agate Creek were surveyed at the cursory level. The 5.6 km stream length of Agate Creek parallels Quartz Creek; however the lower three reaches of Agate Creek are more heavily forested.

Physical

Reach 1 was less than 1 km in length. This reach is characterized by heavy flood damage and an unstable substrate composed primarily of boulder and cobble (Table 38). The high water channel was nearly nine times the width of the stream channel. Small pools of

Table 38. Habitat characteristics for Quartz Creek and Agate Creek, 1985-86.

Habitat Features	Quartz Creek (Stream 1038) Reach 2	Agate Creek (Stream 1039) Reach 1	Reach 2	Reach 3	Reach 4
Sample Date	07/19/85	07/17/85	07/17/85	07/18/85	07/17/86
Time	1000	1030	1500	1100	1415
Stream Order	II	II	II	II	II
Length (km)	1.0	0.8	1.0	1.8	2.0
Elevation:					
Maximum (m)	2249.4	2011.7	2154.9	2327.1	2438.4
Minimum (m)	1999.5	1920.2	2011.7	2154.9	2327.1
Drainage Size (ha)	456.8	1705.0	1669.6	1358.5	870.2
Water Column:					
Flow (m3/s)	0.003 a)	0.033	0.044	0.060	0.014
Channel Width (m)	6.8	17.5	5.9	4.7	6.1
Stream Width (m)	1.0	2.0	2.4	2.1	1.9
Stream Depth (cm)	6.10	9.14	6.10	12.19	6.10
Stream Shore Water Depth (cm)	3.05	6.10	4.57	6.10	0.00
Riffle Width (m)	0.70	0.79	0.64	0.34	0.79
Pools:					
Width (m)	0.3	0.9	1.0	1.4	0.5
Quality	1.0	2.7	2.0	3.1	1.5
Feature	3.7	3.0	2.8	3.8	3.7
Solar Angle		57.0	40.5	25.2	55.3
Channel Morphology					
Streambank Alteration	44.2	33.3	27.5	24.2	33.3
Vegetative Stability	2.5	2.7	2.7	2.7	1.8
Undercut (cm)	6.1	0.0	0.0	9.1	0.0
Channel-Bank Angle	102.2	125.8	128.0	105.0	140.8
Stream Bottom:					
Gradient (%)	18.7	2.2	6.3	4.7	2.7
Sinuosity	1.30	1.00	1.10	1.04	1.20
Substrate:					
Boulder >356 mm	45.7	4.8	27.8	52.1	
Cobble 64-356 mm	48.6	80.5	53.2	31.0	61.0
Gravel 2-64 mm	5.7	14.6	19.0	16.9	16.7
Sand 0.6-2 mm					5.5
Silt <0.6 mm					16.7
Embeddedness	4.67	5.00	4.30	4.67	3.00
Channel Vegetative Cover (cm)	3.30	0.00	0.00	0.00	6.10
Riparian Zone:					
Streamside Cover	1.7	2.0	1.5	2.7	1.7
Vegetative Use	4.20	10.80	4.20	4.2	15.00
Vegetation Overhang (cm)	3.05	15.24	21.34	18.29	0.70
Habitat Type	3,9	2,11	3,12	3,11	9,6

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a) Streamflow estimated by fluorescein dye method.

Table 39. Occurrence and densities of macroinvertebrates found during reconnaissance surveys of Agate Creek and Quartz Creek, 1985 and 1986.

	Agate Creek:	Reach 1	Reach 2	Reach 3	Reach 4	Quartz Creek:	Reach #2
Platyhelminthes							
Turbellaria (planarians)			1				7
Arthropoda							
Insecta							
Ephemeroptera (mayflies)							
Baetidae							
Baetis bicaudatus				7			13
Baetis hageni			6				
Baetis tricaudatus		31	31		3		
Ephemerellidae							
Drunella coloradensis		8	8	1	2		
Drunella doddsi		4					
Ephemerella aurivilla					3		
Heptageniidae							
Cinygmula sp.			3	9	2		12
Epeorus longimanus		7	4	1			
Leptophlebiidae							
Paraleptophlebia sp.							7
Siphlonuridae							
Ameletus sp.			2	1	16		5
Plecoptera (stoneflies)							
Capniidae							
Isocapnia sp.							2
Perlodidae							
Megarcys sp.					5		
Chloroperlidae					2		4
Nemouridae							
Zapada sp.							4
Perlidae							
Doroneuria theodora			1		6		3
Trichoptera (caddisflies)							
Limnephilidae							
Apatania sp.				31			9
Neothremma alicia							81
Rhyacophilidae							
Rhyacophila sp.		3	10		2		15
Glutops sp.				1	3		
Coleoptera (beetles)							
Elmidae							
Stenelmis sp.				2			5
Dystiscidae					1		
Diptera (true bugs)							
Chironomidae			4		5		
TOTAL TAXA:		5	10	8	12		13
TOTAL:		53	70	53	50		167

moderate quality are scattered throughout this reach. Approximately 150 m from the confluence with the Yellowstone River, a series of small cascades may function as a barrier to fish migration during low streamflows. These cascades mark the lower end of a short canyon which ends in a 5 m high waterfall approximately 200 m upstream. The waterfall is a permanent barrier to fish migration.

Stream gradient is steeper in Reaches 2 and 3 (Table 38). Although channel stability is somewhat higher in these two stream reaches, channel alteration is extensive during periods of runoff. Both reaches are bordered by a narrow V-shaped canyon and exposed talus slopes are common. Downed timber is abundant, particularly in Reach 2. Due to the narrowness of the canyon, the majority of the downed timber rests 1-2 m above the water surface and provides limited instream cover. As a result of the heavy riparian growth and steep canyon walls, only minimal amounts of sunlight reach the stream channel in these two stream reaches. Reach 3 contained several large pools formed by boulders (Table 38) which represented the best fisheries habitat in Agate Creek.

Reach 4 differs considerably from the other stream reaches. This reach is enclosed in wide, grassy meadows and sagebrush (Artemisia sp.) hills on the top of Specimen Ridge. Sandhill cranes (Grus canadensis) and a grizzly bear (Ursus arctos horribilis) were observed in this area during the reconnaissance survey. Agate Creek is a small, low gradient, meandering stream in this section. Streambanks are composed primarily of a grass and cobble mixture, and smaller-size substrate particles form a significant portion of the stream bottom (Table 38). Although overhanging grass was common in Reach 4, undercut banks were few in number.

All five tributaries to Agate Creek are moderate gradient (mean = 8.9%) and longer than 1 km in length (Table 40). Only two of the tributaries (103902 and 103903) are perennial streams. Although both of these streams are small (mean width = 1.68 m), together they contribute nearly 40% of the Agate Creek streamflow.

Biological

Macroinvertebrates

The lower three stream reaches in Agate Creek displayed low benthic macroinvertebrate species diversity, but

Table 40. Physical features of tributaries to Quartz Creek and Agate Creek, 1986.

Stream	Stream Order	Watershed Size (ha)	Stream Length (km)	Elevation Maximum (m)	Elevation Minimum (m)	Gradient (%)	Stream Flow (m3/s)	Mean Width (m)	Mean Depth (cm)	Mean Velocity (cm/s)	Temperature (C)
103801	I	320.28	1.91	2438.4	2261.6	9.2					
1039	II	2677.60	5.60	2438.4	1920.2	9.2	0.127	2.92	17.98	23.77	10
103901	I	525.05	2.01	2334.8	2121.4	10.6					
103902	I	467.30	3.12	2474.9	2261.6	6.8	0.012	1.91	7.01	15.85	7
103903	I	446.29	3.08	2584.7	2334.8	8.1	0.012	1.45	4.88	24.08	14
103904	I	188.90	1.81	2548.1	2368.3	9.9					
103905	I	94.50	1.20	2487.2	2380.5	8.9					

density was among the highest of all streams surveyed in 1986. Baetidae was the dominant family of the four Ephemeropteran families represented in Agate Creek mainstem (Table 39). Trichopterans composed at least 10% of sampled invertebrates in each stream reach, except in Reach 1. Plecopterans were a significant group only in Reach 4. This may be a reflection of both higher substrate embeddedness and channel stability in Reach 4.

Aquatic Vertebrates

During the July 1985 survey of Agate Creek, four spawning cutthroat trout (*Salmo clarki*) were captured near the confluence with the Yellowstone River. Mean length of three males was 350 mm and a single female was 314 mm.

Spawning tributaries to the lower Grand Canyon of the Yellowstone River are very limited. Tower Falls is a permanent barrier to fish migration in Tower Creek. A 4 m high waterfall in Deep Creek located approximately 25 m from the confluence with the Yellowstone River also serves as a permanent barrier. Thus, the lower 150 m of Agate Creek take on added significance as a spawning area. On 28 June 1985, the survey team visually counted 67 cutthroat trout in this short section. Counts by National Park Service personnel during spawning season have been as high as 200 trout in Agate Creek (R. King, personal communication, 1985-86). Since this section of stream is accessible by a maintained trail, it is recommended that closure of Agate Creek during spawning season be continued.

HEART LAKE DRAINAGE BASIN

Introduction

Heart Lake is the fourth largest lake in Yellowstone National Park (YNP) and supports the largest native fish species diversity in the park (Dean and Varley 1974; Varley and Schullery 1983). Foremost of these fishes is the Heart Lake strain of Yellowstone cutthroat trout. This subspecies is characterized by above average growth rates and has been considered for additional introductions both within and outside of YNP (Jones et al. 1981). Spawning information on Heart Lake cutthroat trout (*Salmo clarki*) is extremely limited. During the last week of May and the first half of June 1986, Beaver Creek and other tributaries of Heart Lake were investigated in order to gather spawning information concerning trout from Heart Lake.

Methods

Water temperatures were recorded by two methods. Maximum-minimum thermometers were installed in Beaver Creek and the outlet of Witch Creek and read bi-weekly. Instantaneous water temperatures in these two streams and other tributaries in the drainage basin were measured with a hand-held thermometer.

Stream velocity was determined in Beaver Creek and tributaries 302306 and 302308 with a pygmy Gurley meter. Fluorescein dye was used to determine stream velocity in several smaller tributaries.

A 12 m experimental gillnet was used to sample fish in Beaver Creek, Witch Creek, and Heart Lake. The net was 1.5 m deep and divided into two panels of 38 and 51 mm bar mesh size. The majority of sampling was accomplished by overnight sets (Table 41).

Results

Sheridan Creek

Sheridan Creek was the only Heart Lake tributary that was turbid during the survey period. Mean water temperature from three sample dates was 8.1 C (range: 7.2-9.4). Streamflow was 0.320 m^3/s on 1 June and 0.446 m^3/s on 10 June 1986. No fish were observed in Sheridan Creek. The steep gradient (mean = 27.9%) may function as a barrier to upstream fish passage.

Table 41. Gillnetting results for Beaver Creek, Heart Lake, and Witch Creek, 1986.

Location	Set		Pull		Species	Number Sampled	Mean Length (mm)
	Date	Time	Date	Time			
Beaver Creek	30 May	1515	30 May	1645	---	0	---
	30 May	1715	31 May	1000	Cutthroat trout	1	445
	1 June	1830	2 June	1000	Cutthroat trout	2	513
	2 June	1100	2 June	1730	---	0	---
	2 June	1800	3 June	0945	Cutthroat trout	2	473
					Lake trout	1	495
					Utah sucker	1	468
	3 June	1200	3 June	1445	Cutthroat trout	1	410
	9 June	1800	9 June	1930	Utah sucker	1	470
	9 June	1945	10 June	0930	Cutthroat trout	2	475
					Utah sucker	6	457
	10 June	1230	10 June	1900	Cutthroat trout	2	481
	10 June	1930	11 June	1000	Cutthroat trout	1	521
					Utah sucker	8	473
	11 June	1100	11 June	1700	Cutthroat trout	3	516
					Utah sucker	3	540
	11 June	1930	12 June	0915	Cutthroat trout	2	494
					Utah sucker	4	481
	12 June	1100	12 June	1745	Cutthroat trout	1	546
					Utah sucker	3	473
	21 June	1830	22 June	1030	Cutthroat trout	5	465
					Utah sucker	21	493
Heart Lake	20 June	2115	21 June	1030	Lake trout	7	485
					Cutthroat trout	7	329
					Utah sucker	11	---
					Utah chub	23	---
	21 June	1630	22 June	0830	Lake trout	5	---
					Cutthroat trout	2	508
					Utah sucker	23	321
					Utah chub	16	241
					Mountain whitefish	3	288
Witch Creek	30 May	1900	1 June	0930	Utah chub	23	331
					Utah sucker	1	387
	20 June	1915	21 June	1015	Utah sucker	1	419

Witch Creek

Numerous thermal features in the Witch Creek drainage contribute to its uniqueness. Upper stream sections have high temperatures which form a thermal barrier to fish. Cooler temperatures allow for some fish activity in the lower section of the stream. Water temperatures were recorded at four sites in Witch Creek: the inlet into Heart Lake, the upper and lower trail bridges, and unnamed tributary 302305. In addition, a maximum-minimum thermometer was placed at the stream mouth. Water temperatures in Witch Creek ranged from a low stream mouth temperature of 7.8 C on 1 June to 33.3 C at the lower meadow bridge on 22 June.

Spawning activity was monitored from the mouth of Witch Creek to stream 30230503. Utah chubs (Gila atraria) and Utah suckers (Catostomus ardens) were captured in overnight gillnet sets in the outlet of Witch Creek (Table 41). During the week of 29 May - 4 June, Utah suckers were abundant in Witch Creek, and spawning activity was frequently observed. Although there was a concentration of suckers at the confluence of tribuary 30230503 and Witch Creek, no suckers moved into the tributary. The tributary temperature of 9.4 C on 2 June may have acted as a cold water barrier to the suckers. The sucker spawning run in Witch Creek was completed by 9 June. On 20 June, speckled dace (Rhinichthys osculus) were observed in tributary 302305. No fish were observed after this date, and lower flows and higher temperatures were noted.

Stream 302306

This small tributary to Heart Lake flows through the burn area 0.5 km west of Beaver Creek (Figure 24). Discharge, measured 100 m upstream from the creek mouth on 30 May was 0.024 m^3/s. Instantaneous water temperatures ranged from 7.2 C (31 May) to 18.9 C (10 June).

On 21 June, numerous redside shiners (Richardsonius balteatus) were observed in this tributary both above and below the trail crossing bridge.

Beaver Creek

A maximum-minimum thermometer was installed in Beaver Creek approximately 100 m upstream from the outlet to the lake. Instantaneous water temperatures were also taken. Although Heart Lake contained ice cover at the

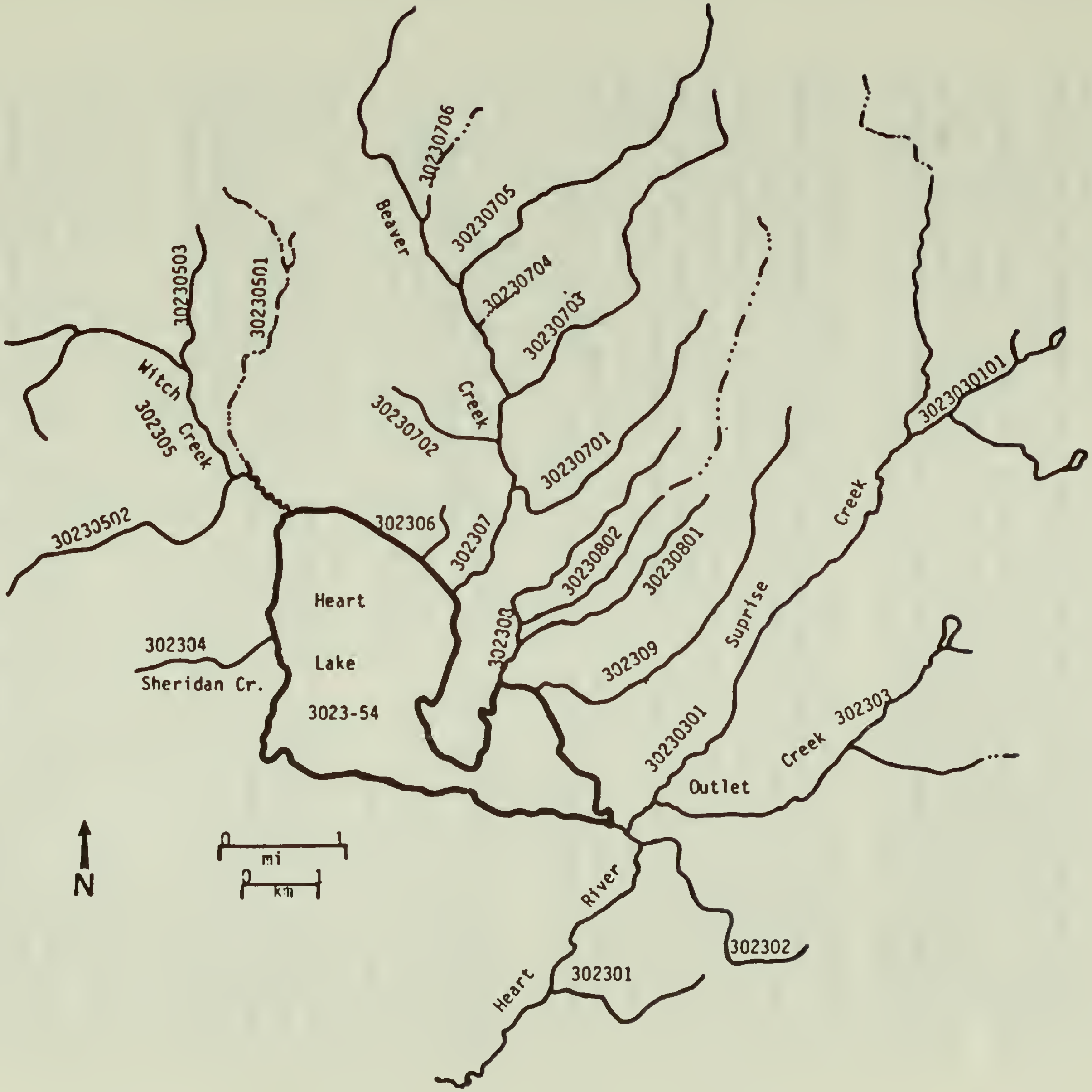

Figure 24. Tributaries of Heart Lake and Heart River, 1986.

end of May 1986, Beaver Creek water temperature exceeded 14 C (Appendix A Table 11).

Daily streamflow in Beaver Creek was measured at a point approximately 0.4 km upstream from the inlet to the lake. The majority of flows were greater than 2 m^3/s (Appendix A Table 12). Beaver Creek was clear throughout the study period. Peak discharge occurred on 1 June. Stream discharge 50 m downstream from tributary 30230705 was 0.799 m^3/s on 11 June 1986.

The section of Beaver Creek from the inlet to Heart Lake to a point 3 km upstream was surveyed on 2 June, and the lower 5 km of Beaver Creek were surveyed on 11 June. The survey area encompassed many meadows bordering the burn area. Although no snow was visible in the adjacent hills during the surveys, Beaver Creek was characterized by the overbank flows in the lower meadows. The upper 2 km of Beaver Creek, surveyed on 11 June, flows through a wooded canyon. This section of stream is characterized by numerous rocky pools, and spawning gravel is extremely limited.

On 2 June, streamflow in tributary 30230701 was estimated to be 0.543 m^3/s. Average stream width of this stream was 2.4 m. Discharge in tributary 30230705 was 0.475 m^3/s on 11 June. No fish were observed in either tributary.

Several gillnet samples in Beaver Creek failed to document a substantial cutthroat trout spawning migration (Table 41). All captured cutthroat trout were either immature or spent fish. In contrast, the Utah suckers were mature spawners, and spawning was observed frequently during the last half of June.

Stream 302308

The unnamed tributary flowing into Heart Lake on the east side of the promontory drains a large marshy area that is presently exhibiting effects form the 1979 burn. As a result, the upper portions of this stream exhibit a deep burgundy color. Extensive chemical analyses revealed that this stream was very dilute, (total dissolved solids (TDS) = 15 mg/l). Nearly every chemical constituent was well below the parkwide average (Table 25). The most distinctive chemical feature was the high color unit concentration (Table 25).

High flows in this watershed formed a small lagoon (0.4 km in diameter) at the inlet to Heart Lake. The combination of snowmelt and overbank flows resulted in numerous braided channels and seeps at the lagoon's upstream edge. The stream banks are undercut, and the majority of the stream bottom is a sand/silt mixture.

Streamflow was determined at a site approximately 0.5 km from the mouth of the stream. Measured streamflows at this site on 31 May and 12 June were 0.634 m^3/s and 0.330 m^3/s, respectively. Water temperature varied from a low of 13.9 C at the flow site to 20 C in the lagoon.

On 12 June, numerous fishes were observed. Speckled dace were found in the upper marsh area. The main stream channel in the vicinity of the flow transect contained nearly a dozen Utah suckers, two cutthroat trout, and numerous redside shiners. The lagoon area contained many small fish: redside shiners, speckled dace, and possibly young suckers.

Streambanks in tributary 30230802 had sustained severe high water damage, resulting in a large sediment contribution to the mainstem of stream 302308. Streamflow in tributary 30230802 was 0.282 m^3/s. Water temperature was 9.4 C on 12 June. No fish were observed in this degraded stream.

Discussion

The number of spawning tributaries to Heart Lake appears to be limited. High water temperature in Witch Creek forms a thermal barrier to salmonid spawning. The majority of the other surveyed tributaries lack suitable spawning gravel and are dominated by a silt-sand bottom substrate.

In contrast, Beaver Creek contains excellent spawning habitat and abundant gravel. Although a concentrated Utah sucker spawning migration (400-500 fish/km) was noted during the last half of June, this did not hold true for the cutthroat trout. Individual cutthroat trout were only occasionally observed in Beaver Creek. There were no observations of spawning cutthroat trout activity, and no redds were seen. The vast majority of cutthroat trout caught in the gillnets were spent fish.

Water temperature may be a key limiting factor in Beaver Creek. Jones et al. (1984-86) have shown that water temperature influences the timing of cutthroat trout spawning runs in tributaries to Yellowstone Lake. Migrations often peak as mean daily temperature approaches 10 C. Higher temperatures are more favorable to suckers. This scenario coincides with the observations in Beaver Creek. As a result, Beaver Creek cutthroat trout may spawn very early in the year, possibly beginning in late April.

Limited numbers of spawning cutthroat trout in Beaver Creek may also be a reflection of interspecific competition with suckers, chemical effects due to the 1979 forest fire, or other undetermined factors. Consequently, Heart Lake cutthroat trout may concentrate their spawning efforts at an alterantive site (Outlet Creek or Heart River). Additional investigations should provide clarification of Heart Lake cutthroat trout spawning dynamics.

GARDNER RIVER SPAWNING SURVEY

Introduction

Successful trout fishery management in streams and rivers which flow across boundaries of Yellowstone National Park (YNP) often requires the cooperation of federal and state agencies, as well as the support of private landowners and anglers. Currently, the Montana Department of Fish, Wildlife, and Parks (MDFWP) is studying trout populations in the mainstem Yellowstone River and tributaries between the northern boundary of YNP and Livingston, Montana (MT). The Gardner River, the major tributary in this section, originates in YNP and joins the Yellowstone River at Gardiner, MT (Figure 25). In response to a request from the MDFWP, the U.S. Fish and Wildlife Service and the MDFWP cooperated in an investigation to determine the extent of brown trout (*Salmo trutta*), rainbow trout (*S. gairdneri*), cutthroat trout (*S. clarki*), and rainbow x cutthroat trout hybrid spawning migrations from the Yellowstone River into the Gardner River.

Methods

Fish were sampled in the Gardner River on 31 October 1985 and on 3 and 25 March 1986. The study section extended from the U.S. Geological Survey gage house near the 45th parallel to a point approximately 0.6 km downstream (Figure 25).

Fish were collected by electrofishing. A 4-m long rubber raft was outfitted with two stationary dropper electrodes (one positive and one negative) and one mobile positive electrode. The raft contained fish-holding tanks, a generator, and a Coffelt VVP-15 rectifying unit that output pulsed, direct current. Electrofishing began at the upstream boundary of the study section and proceeded downstream. Two crew members stood in the river at the upstream end of the raft and guided it slowly downstream as other personnel stood near the positive electrodes and netted stunned fish. Netting was size-selective by species; only brown trout suspected to be spawners were collected in October 1985, and only rainbow trout, cutthroat trout, and hybrid trout suspected to be spawners were netted in March 1986.

Captured fish were anesthetized in MS-222, identified to species, and measured to the nearest 1 mm total length (TL); sex and spawning condition were determined when

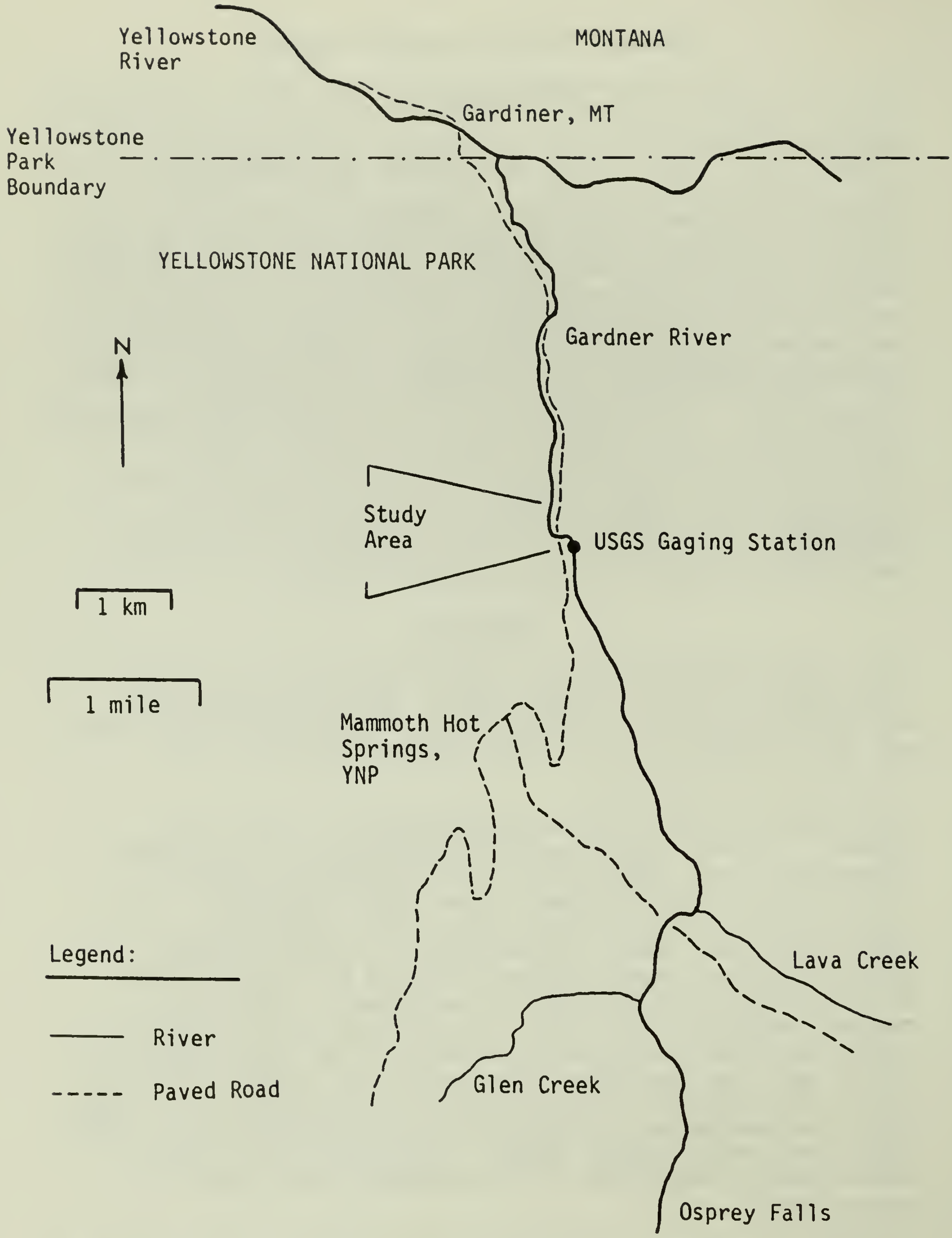

Figure 25. Map of Gardner River, Yellowstone National Park, showing study area investigated during spawning surveys in October 1985 and March 1986.

possible. In October 1985, brown trout greater than 350 mm TL were tagged with individually numbered Floy tags. In March 1986, only selected rainbow trout were tagged. After being revived in fresh water, fish were released within the boundaries of the study section.

Results

Brown trout

A total of 240 brown trout spawners were captured in October 1985. Mean lengths of males (n=106) and females (n=134) were 400 and 375 mm, respectively. Two hundred five of these fish were tagged before release, and to date, 11 have been recaptured by electrofishing or angling. One brown trout was recaptured at the mouth of the Gardner River, while the remainder were collected in the mainstem Yellowstone River downstream of the confluence with the Gardner River (Appendix A Table 13).

Rainbow trout, cutthroat trout, and rainbow x cutthroat trout hybrids

Forty rainbow trout spawners were captured in the Gardner River in March 1986. Male (n=28) and female (n=12) mean lengths were 312 and 356 mm, respectively. Thirty-one of these fish were tagged before release, and only one has been recaptured to date (Appendix A Table 14). The one cutthroat trout spawner captured (male, 383 mm TL) and the 10 hybrid trout caught (all males, mean length 286 mm) were not tagged before release.

Discussion

Recapture data indicate that brown trout from the Yellowstone River use the Gardner River as a spawning stream; however, data for rainbow trout, cutthroat trout, and rainbow x cutthroat trout hybrids are inconclusive. Future work should focus on confirming whether rainbow trout, cutthroat trout, and hybrid trout migrate from the Yellowstone River into the Gardner River to spawn.

LAMAR RIVER (VALLEY CATCH AND RELEASE SECTION)

Introduction

The Lamar River is one of the most popular stream fisheries in Yellowstone National Park (YNP) (Table 5). A wide, picturesque valley and highway access heighten the appeal of this river to anglers. The section of the Lamar River from Cache Creek downstream to the confluence with the Yellowstone River has been restricted to catch and release fishing since 1973. The valley portion of this catch and release area extends from Cache Creek to the Lamar River Canyon. Fishery surveys on this section of the Lamar River have attempted to monitor the response of the fishery to the catch and release regulation (Jones et al. 1985).

Results and Discussion

On 4 September 1986, day-time sampling by electrofishing was conducted from the confluence of Lamar River with Soda Butte Creek downstream for approximately 2.2 km. Mean length of 48 rainbow x cutthroat trout hybrid (*Salmo gairdneri* x *Salmo clarki*) was 277 mm (Figure 26). Although this is significantly smaller than the mean length of 313 mm (n=55) for rainbow x cutthroat trout hybrids sampled during the August 1984 survey (Jones et al. 1985), PSD's for the fall 1986 and 1984 surveys were similar (11.9% and 16.4%, respectively). Lower mean length in 1986 may be due to the capture of more fish under 200 mm rather than a significant change in population structure. One mountain sucker (*Catostomus platyrhynchus*) (TL = 106 mm) and one longnose dace (*Rhinichthys cataractae*) (TL = 45 mm) were also collected.

In 1986, the Lamar River received nearly 2.5% of the total angling use in YNP (Table 5), and approximately 39% of the use on the Lamar River was concentrated in the section from Cache Creek downstream to Lamar Canyon. Following a dramatic reduction in fishing effort in 1982, there has been a gradual increase back to average levels of effort (Figure 27). Since 1979, there has been a strong positive correlation (r=0.85) between angler effort and the number of trout landed in this section of the Lamar River. The landing rate (0.91 fish/hr) in 1986 was the second lowest since 1979. Mean length of landed trout in 1986 (297 mm) was slightly below the 8-year average (305 mm).

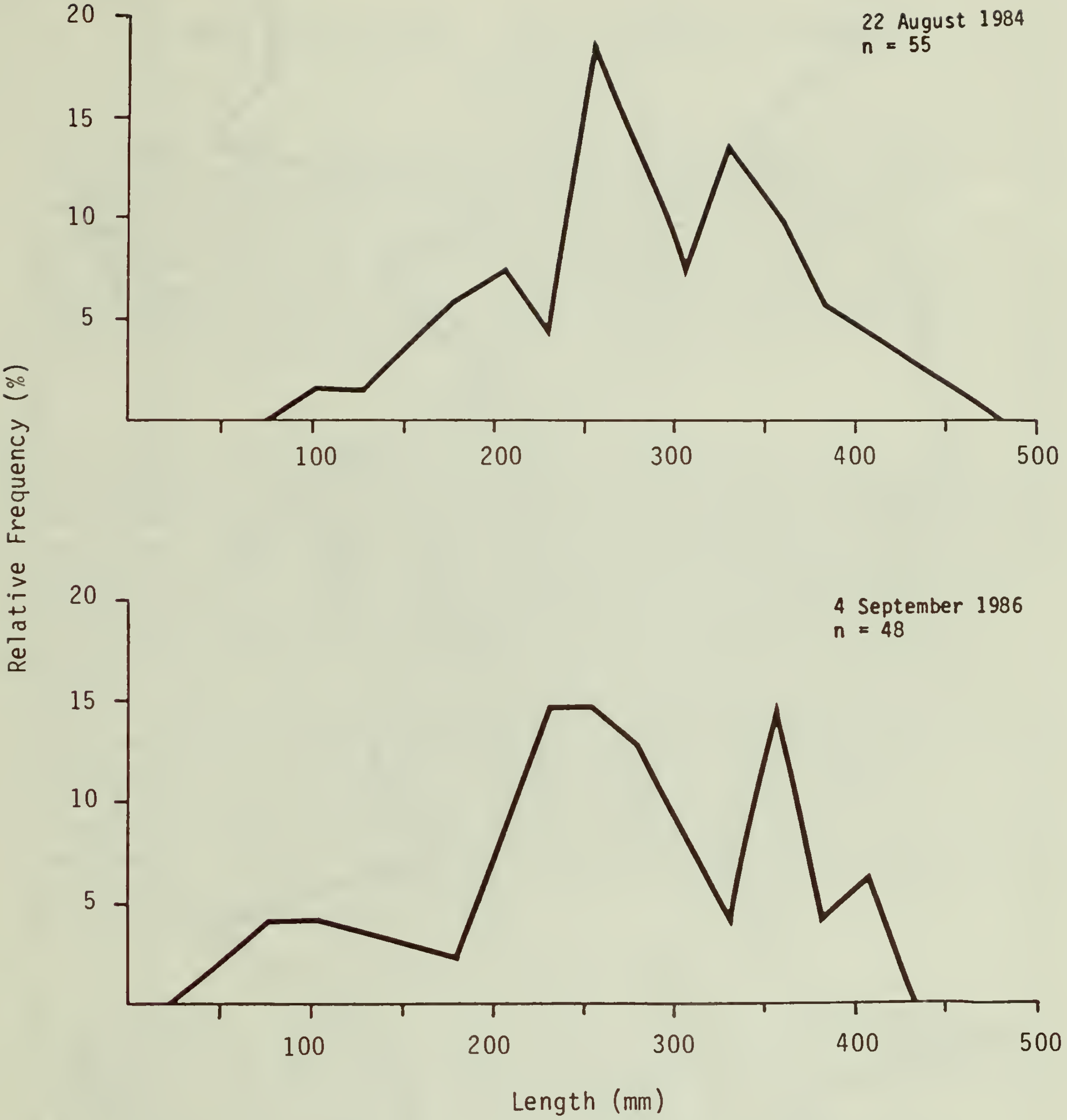

Figure 26. Length distribution of rainbow x cutthroat trout hybrids captured in the Lamar River on 22 August 1984 and 4 September 1986.

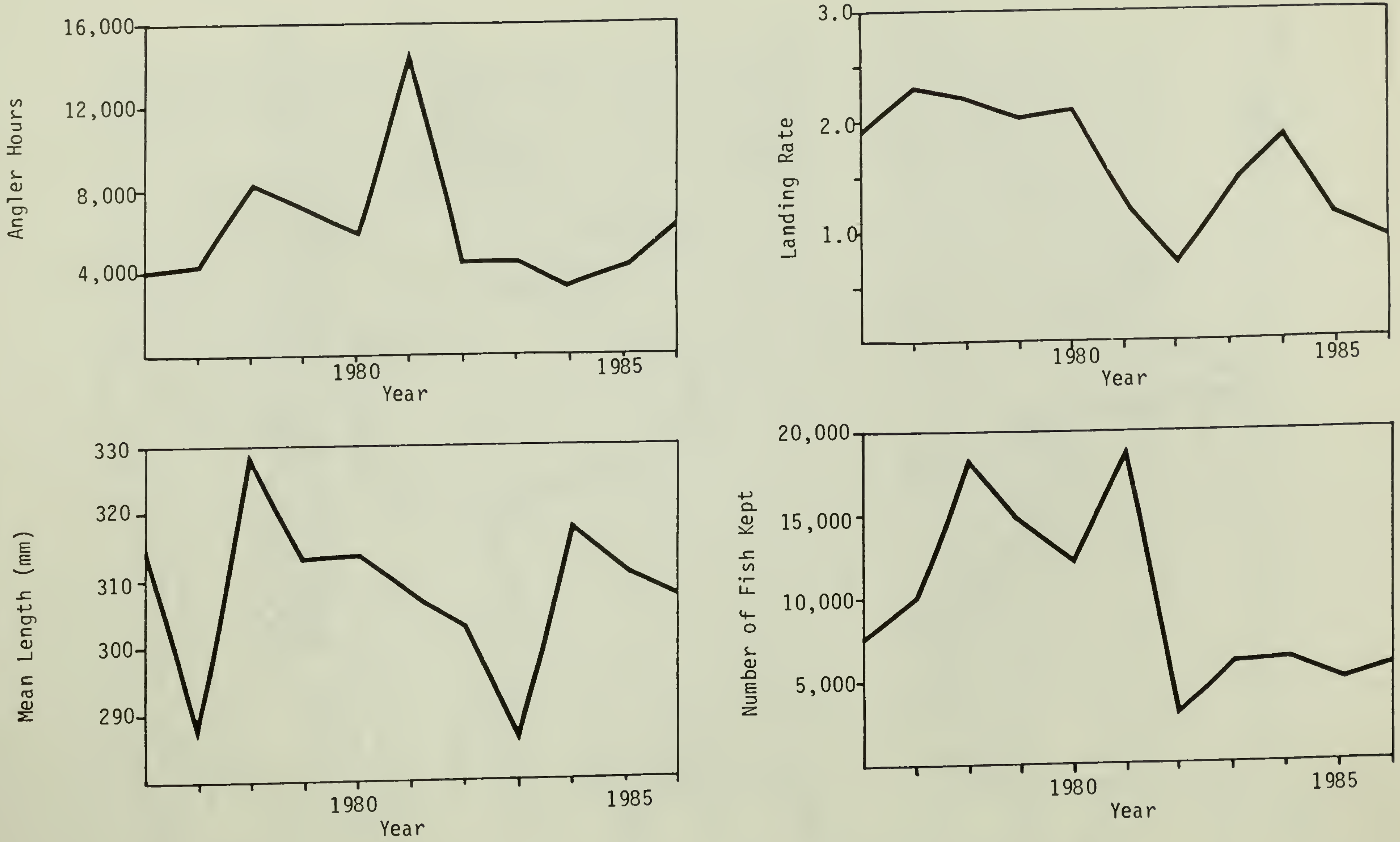

Figure 27. Angler statistics for the valley section of the Lamar River, 1976-86.

SODA BUTTE CREEK - FISH POPULATION SURVEY

Physical

The Soda Butte Creek drainage was formed by Absaroka volcanic flows. Major glacial activity carved a wide valley in the lower sections of Soda Butte Creek and massive landslides from both Druid Peak and The Thunderer have had a major influence on present topography. The Madison limestone formation underlies the majority of the stream and sporadic outcroppings occur throughout the drainage (Parsons 1978).

Chemical

In 1986, extensive water chemistry analyses were conducted at four sites in Soda Butte Creek: Northeast boundary of Yellowstone National Park (YNP) (upper station), confluence with Warm Creek, below Lamar Trail Footbridge (lower station), and the confluence with Lamar River. Total dissolved solid (TDS) values of this calcium-bicarbonate stream generally increased in a downstream direction (Table 35). While TDS remained high, there was a shift to a magnesium bicarbonate water type at the Footbridge site. The most likely source of the magnesium influx may be a dolomite outcropping, particularly from the lower drainage of tributary 10331705. Sulfate, iron, and total organic carbon concentrations are above park average at the park boundary. These values may indicate continuing chemical influences from the McLaren mine tailings and Cooke City, Montana, sewage lagoon.

Fish Population Survey

In September 1986, fish population surveys were conducted on two sections of Soda Butte Creek. The upper sampling section begins at the Northeast park boundary and continues downstream for 305 m. Twenty-three rainbow x cutthroat trout hybrids (*Salmo gairdneri* x *Salmo clarki*) were captured. Mean length was 250 mm, and only one fish was over 330 mm. Due to the small sample size and lack of recaptures, a population estimate was not possible. Although streamflow (and resulting pool cover) was nearly 25% greater than in 1985, total number of fish captured in 1986 was approximately one-third the size of the 1985 sample. A large thunderstorm and subsequent heavy flooding on 21 August may have caused some downstream displacement of the population in this upper section of Soda Butte Creek.

The lower (Footbridge) study section encompasses the area from the Lamar River trailhead bridge to the confluence with the Lamar River. Three marking passes through this 2.3 km section in 1986 yielded 289 rainbow x cutthroat trout hybrid and 2 rainbow trout. Due to a limited number of recaptures in Soda Butte Creek (n=12), all fish were combined in order to obtain an unbiased population estimate. The adjusted Peterson estimate was 1,258 (95% C.L. = 779-2,637) or 539 trout/km. The population estimate in 1984 was somewhat larger (1,460 trout) but this difference was not statistically significant.

Mean length and weight of all captured trout in 1986 was 234 mm (n=345) and 158 g, respectively (Figure 28). Approximately 6.7% of these trout were longer than 330 mm. Five year classes were represented in the sample (Table 28). Fifty-four percent of the trout were age 3, and mean age was 2.9 years. Twenty-five longnose dace (Rhinichthys cataractae) (mean length = 90 mm) and 33 mountain suckers (Catostomus platyrhynchus) (mean length = 131 mm) were also collected during the sampling period.

Angler Use

Soda Butte Creek is one of the more popular stream fisheries in Yellowstone National Park and received almost 1.5 percent of the total parkwide angling effort in 1986. Since 1973, Soda Butte Creek has had a 2 fish, any size, creel regulation. In 1986, an estimated 853 trout were creeled from Soda Butte Creek. This represents the lowest number of trout kept in the past 10 years (Figure 29). Nearly 31% of these trout were longer than 330 mm. In the upper section of the stream (above Icebox Canyon), mean lengths of landed and creeled fish were 233 mm and 270 mm, respectively. Mean length of both landed fish (241 mm) and creeled trout (293 mm) below Icebox Canyon was larger than in the upper section. In 1986, there was a shift in angler effort to the upper section of Soda Butte Creek (Figure 29). Possibly as a result of reduced angler effort, the landing rate below Icebox Canyon was the highest in the past decade.

In spite of relatively constant fishing effort and decreasing numbers of creeled trout, the mean length of landed fish continued to drop in 1986 (Figure 29). Soda Butte Creek sustains the third highest creel rate in YNP. It appears that this level of harvest has had a deleterious effect on the cutthroat trout population in

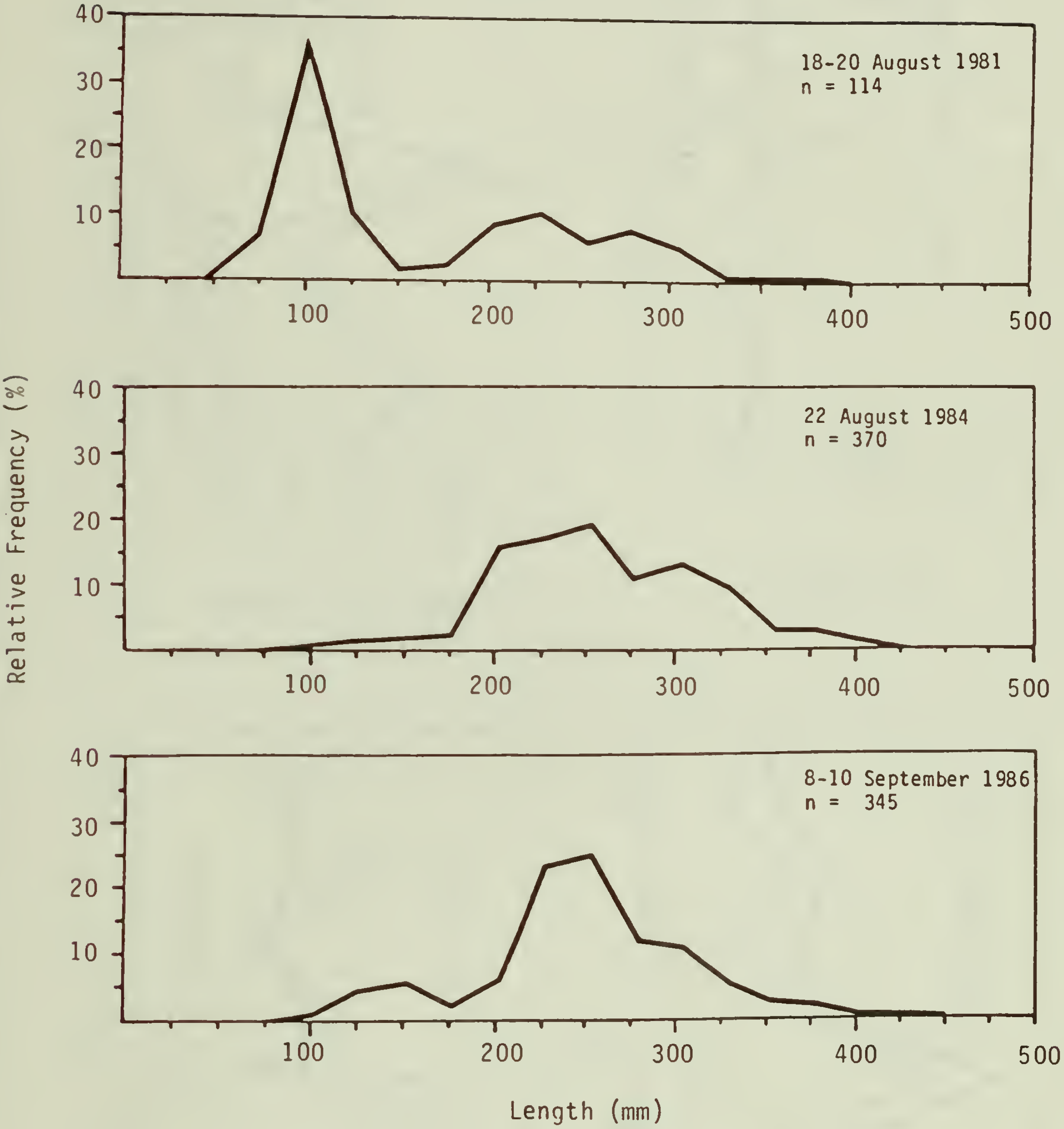

Figure 28 . Length distribution of rainbow x cutthroat trout hybrids captured in the Footbridge sample section of Soda Butte Creek, 1981, 1984, and 1986.

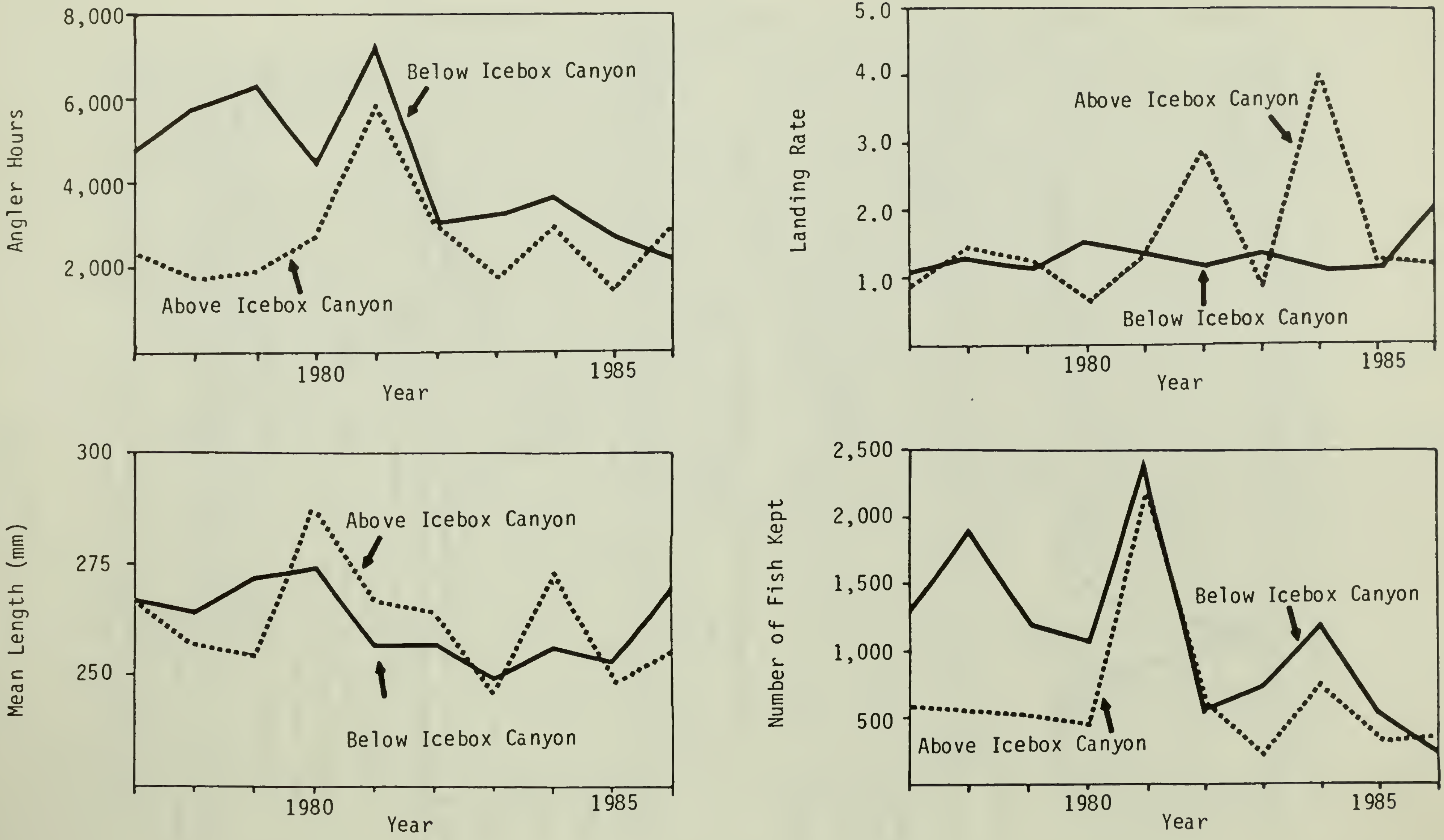

Figure 29. Angler statistics on Soda Butte Creek, Yellowstone National Park, 1977-86.

Soda Butte Creek. Institution of a 330 mm minimum size limit in 1987 may allow this population to rebuild to historical levels.

WARM CREEK

Warm Creek is a small tributary of Soda Butte Creek that originates from a spring approximately 3.2 km downstream from the northeastern park boundary (Figure 20). Water chemistry analyses classified Warm Creek as a calcium bicarbonate alkaline stream. Total dissolved solid concentration (175 ppm) was the greatest of any stream surveyed in 1986.

Since 1982, there have been undocumented reports of anglers landing brook trout (*Salvelinus fontinalis*) in this area of Soda Butte Creek. In September 1986, the entire length of Warm Creek (0.9 km) was electroshocked in order to determine the species composition of this stream. Three cutthroat trout (*Salmo clarki*) were the only fish captured. Mean length was 129 mm and mean weight was 18.7 g. Two fish were aged as II+ (Table 28).

MADISON RIVER

Introduction

The nationally renowned Madison River is the second most popular stream fishery in Yellowstone National Park. Brown trout (*Salmo trutta*), rainbow trout (*Salmo gairdneri*), and mountain whitefish (*Prosopium williamsoni*) comprise the majority of the fishery. Historically, fluvial Montana grayling (*Thymallus articus*) and westslope cutthroat trout (*Salmo clarki lewisi*) dominated this fishery. However, these latter two species have been virtually eliminated from the present day fishery.

Due to the importance of the Madison River fishery, numerous studies have been conducted to assess the impacts of angling on the fishery (Jones et al. 1981). Recent studies have focused on population estimates and fish population structure in the Madison River (Jones et al. 1985, 1986). In the past few years, McBride Lake cutthroat trout (*Salmo clarki bouvieri*) have been stocked in Hebgen Lake, Montana, by Montana Department of Fish, Wildlife, and Parks. In June 1986, a survey was conducted to determine the extent of the cutthroat trout migration into the Madison River within Yellowstone National Park and to continue monitoring the population structure of other species in the Madison River fishery.

Methods

Two study sections were selected in the Madison River. The upper study section (above 7-Mile Bridge) began at the confluence of the Firehole River and Gibbon River and continued downstream for 4.2 km. The lower section (below 7-Mile Bridge) started at the Barns portion of the river and ended 6.0 km downstream. These same two study sections were used during the 1984 survey. Only relative comparisons can be made with the spring 1978 survey because the 1978 survey sections were longer and equipment and techniques were different than that employed during 1984 and 1986.

A four-person raft with one positive and one negative boom electrode was utilized during nighttime electroshocking in each survey section in 1986. All captured fish were measured to the nearest 1 mm total length (TL). Fish in a subsample of each species were weighed to the nearest 5 g, and scale samples were collected for age and growth analyses.

Results

The June 1986 sampling in the upper section yielded 66 brown trout, 5 rainbow trout, 88 mountain whitefish, and 2 mountain suckers (Catostomus platyrhynchus). Mean lengths of these species were 334, 255, 304, and 228 mm, respectively. In 1984, mean lengths of brown trout, rainbow trout, and mountain whitefish were 227, 256, and 350 mm, respectively (Figures 30 and 31). The 1978 survey yielded mean lengths of 285, 240, and 317 mm, respectively, for the three species. Proportional Stock Density (PSD) for brown trout increased from 14.58% in 1984 to 15.15% in 1986; however, this was less than the 1978 value (23.65%). Whitefish exhibited a slight decrease (98.8% in 1984 to 95.45% in 1986), yet remained at a high level. The small number of rainbow trout collected were all below the quality length (Gabelhouse 1984) of 419 mm.

In the lower section of the Madison River, 35 brown trout, 2 rainbow trout, 256 mountain whitefish, 4 mottled sculpins (Cottus bairdi), and 2 longnose dace (Rhynichthys cataractae) were captured in June 1986. Mean length of brown trout, rainbow trout, and mountain whitefish was 357, 215, and 306 mm, respectively. The corresponding values in 1984 were 301, 273, and 273 mm, respectively (Figures 30 and 31). In 1978, mean length of brown trout was 285 mm. Rainbow trout and mountain whitefish lengths were 240 and 371 mm, respectively. The PSD value for brown trout increased substantially from 28.57% in 1984 to 48.48% in 1986 in the lower survey section. Whitefish also exhibited a large increase (81.90% in 1984 to 97.66% in 1986). The decrease in PSD for rainbow trout was dramatic (18.75% to 0%). Four age classes of brown trout were represented in the sample (Table 42).

Angler effort on the Madison River in 1986 was the lowest since 1980 and reflected the general decreasing trend in angler use on the Madison River (Figure 32). This decrease in use was reflected in below-average numbers of creeled fish. Landing rates both above and below 7-Mile Bridge have varied slightly since 1980 but have essentially remained above 0.5 fish/hr. Examination of mean length of landed fish (all species combined) reveals a downward trend, particularly above 7-Mile Bridge (Figure 32). Results from Volunteer Angler Report surveys showed that small rainbow trout (203-254 mm) composed the highest percentage size group in the catch in the upper section. In addition, a substantial shift in species composition of the catch

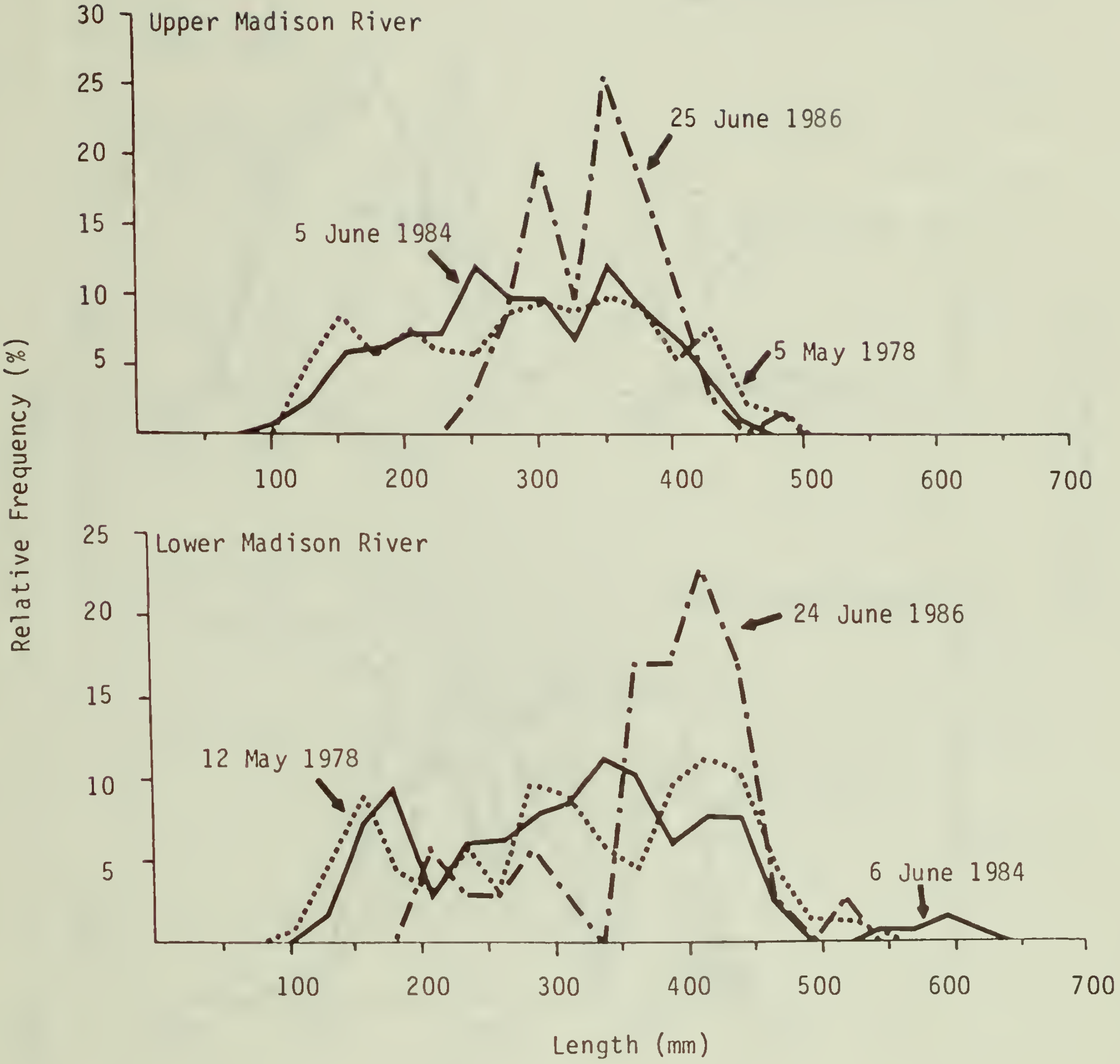

Figure 30. Length distribution of brown trout captured in the upper and lower sample sections of the Madison River in 1978, 1984, and 1986.

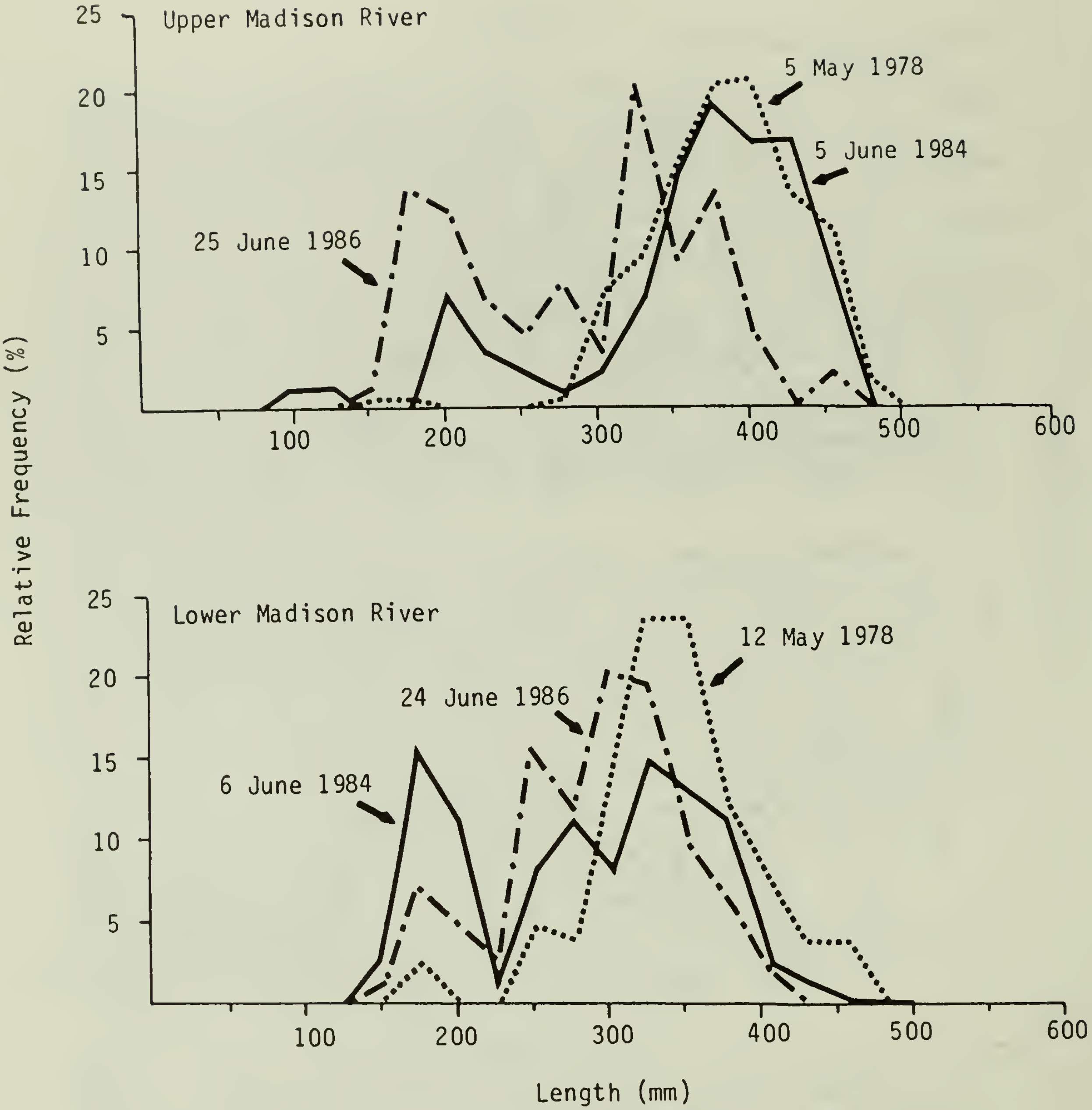

Figure 31. Length distribution of mountain whitefish captured in the upper and lower sample sections of the Madison River in 1978, 1984, and 1986.

Table 42. Back-calculated mean length at annulus formation for salmonids, 1986.

Survey Section	Species	Sample Size	Length (mm) at Age						
			I	II	III	IV	V	VI	VII
Beaver Creek	Cutthroat	18	74	144	232	335	419	478	492
	Lake	1	54	113	199	321	393	488	
Heart Lake	Cutthroat	7	74	140	216	300	355	444	
	Lake	8	67	130	209	293	370	453	512
Madison River									
Lower Section	Brown	11	95	230	322	381			
Upper Section	Brown	8	97	209	298				
All Fish	Brown	19	96	221	312	381			

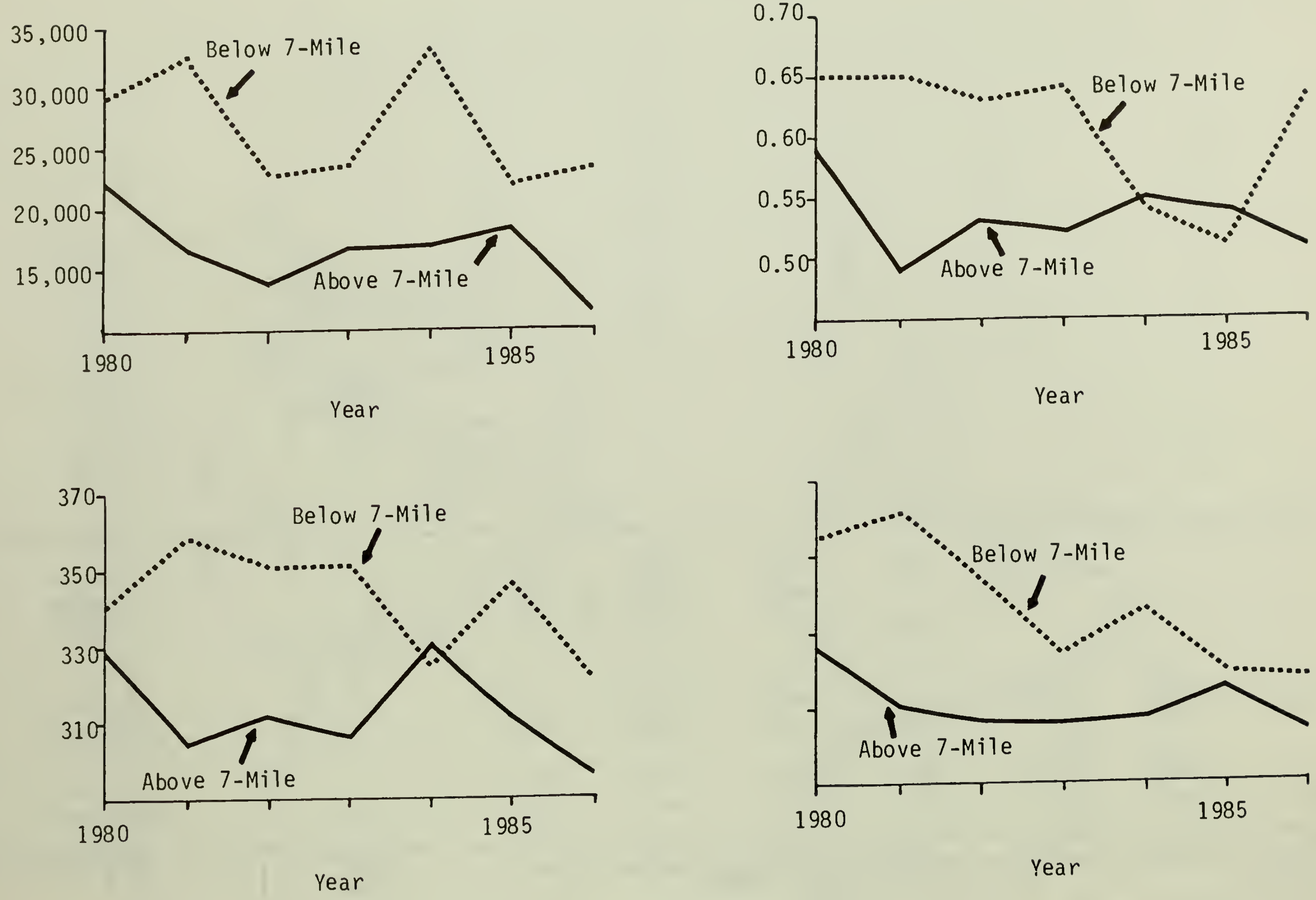

Figure 32. Angler statistics for above and below 7-Mile Bridge of the Madison River, 1980-86.

occurred in 1986 (Figure 33). Percentages of brown trout were at a near record low, while rainbow trout reached one of the highest levels to date.

The increasing numbers of rainbow trout in the catch may be a reflection of a strong year class, greater catchability of rainbow trout versus brown trout, or a combination of both factors. However, electrofishing in June 1986 yielded only a minor percentage of rainbow trout. Angler harvest is currently directed on the older mature fish. Current data suggest that the rainbow trout population in the Madison River is depressed and further protection of these stocks may possibly improve the population structure. Implementation of a catch and release regulation in 1987 should provide needed protection for the rainbow trout population.

Due to less vulnerability to anglers, Madison River brown trout have maintained a healthy population and only a small percentage of these fish are creeled. Fluctuations in mean length and PSD's may indicate an equilibrium situation, particularly in a multispecies fishery. However, the population above 7-Mile Bridge is at less than optimum levels. Numbers of brown trout over 406 mm are in the minority, so this fishery could possibly be improved by changing current angler impacts. Beginning in 1987, the Madison River will be managed under a 2 fish, 254 mm maximum size limit. If successful, this regulation should increase the numbers of older and larger brown trout and concentrate harvest on small immature fish. Continued monitoring of this river is necessary in order to determine the effects of a different angling regulation on the Madison River fishery.

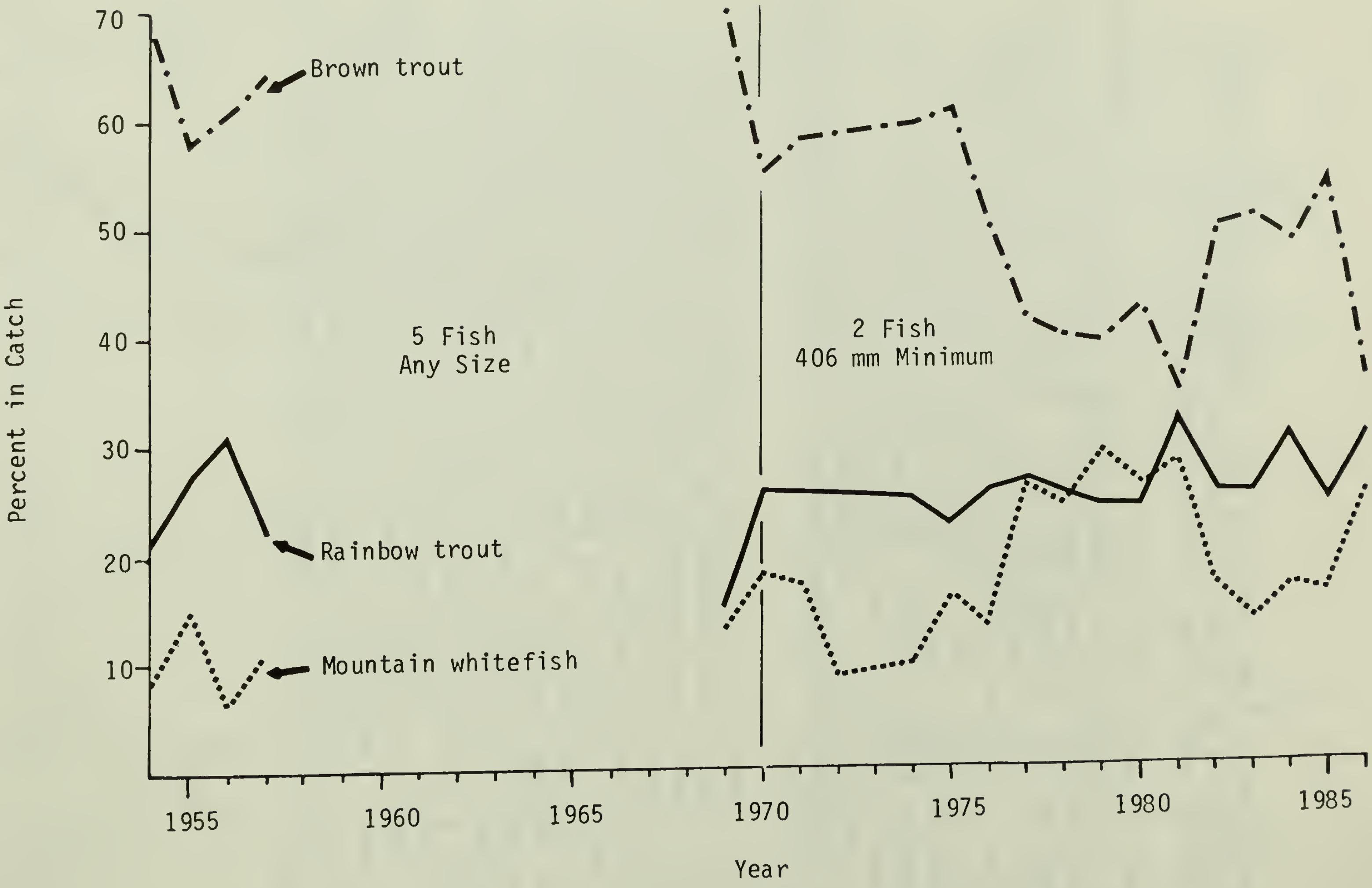

Figure 33. Species composition of fish caught by anglers in the Madison River, 1954-86.

LAKE TROUT SPAWN-TAKING OPERATION

Lewis Lake was historically fishless (Jordan 1891), and initial plants of lake trout (Salvelinus namaycush) and brown trout (Salmo trutta) occurred in 1890 (Varley 1981; Visscher 1984). Lake trout for this introduction were collected from spawning reefs near the Beaver Islands in Lake Michigan (Visscher 1984). Since Lewis Lake is only 4.8 km downstream from Shoshone Lake, rainbow trout (Salmo gairdneri) and brook trout (Salvelinus fontinalis) probably gained access to Lewis Lake soon after they were stocked into tributaries of Shoshone Lake in 1893 and 1895, respectively (Varley 1981). The only other occasion when fish were planted into either lake occurred in 1941; 5,890 lake trout fingerlings were obtained from Bozeman, Montana Fisheries Station and released into Lewis Lake (Visscher 1984).

Efforts to reestablish lake trout in the Great Lakes have been hampered by the use of poorly suited donor stocks. These failures have resulted in current strategies that include selecting stocks which prefer habitat characteristics similar to those of the receiving habitat (Ihssen 1984). Limited lake trout introductions in Lewis Lake have reduced the potential for genetic mixing within this species, and thus, the integrity of the Beaver Island strain has probably been maintained. Virtual genetic isolation of lake trout in Lewis Lake, therefore, made this stock an excellent candidate for reestablishment efforts in Lake Michigan.

To this end, annual collection of sex products from Lewis Lake lake trout was initiated in 1982 (Jones et al. 1983). Both eggs and sperm were collected in 1982, 1983, and 1985, but 1984 collections were limited to sperm alone. Collections were limited to sperm again in 1986.

Methods

Lake trout were collected by electrofishing from boats with boom mounted dropper electrodes (Novotny and Priegel 1974). Pulsed direct current (80 pulses/s) was utilized with a voltage between 100 and 200 volts. Trout were captured at three sites along the east shore of Lewis Lake (Figure 34). Stunned fish were netted and placed into a boat-mounted livewell to recuperate. Periodically, trout from the electrofishing boats were transferred to a 9-m barge for processing.

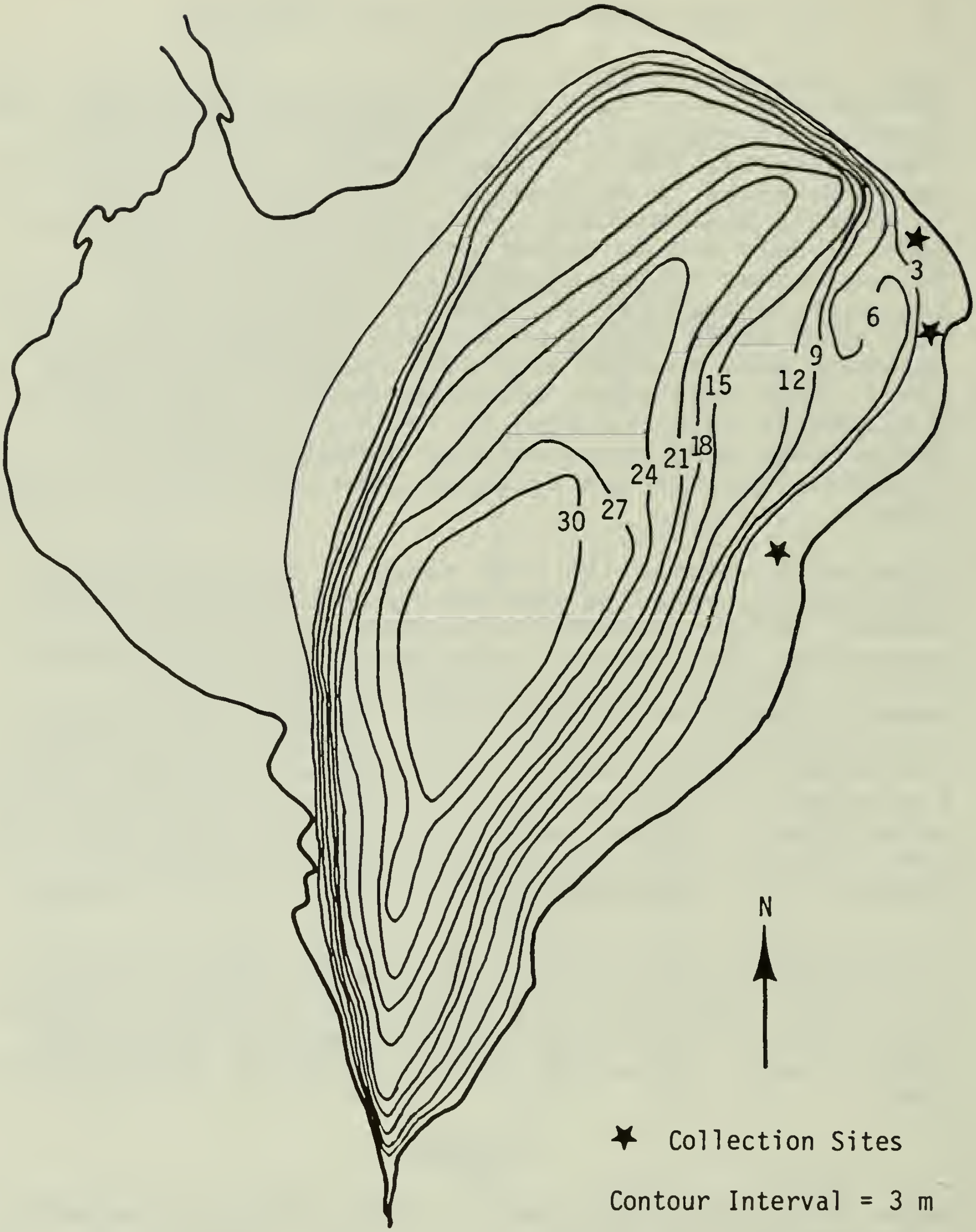

Figure 34. Collection sites for spawn-taking operations, Lewis Lake, 1986.

Disease samples were obtained from 60 lake trout on 24 September 1986. All of these trout were sacrificed for liver and kidney samples; fecal matter was also collected. Samples were shipped to the U.S. Fish and Wildlife Service (USFWS) Disease Control Center (Ft. Morgan, Colorado) for analysis. Tests were made for the following pathogens: *Aeromonas salmonicida*, enteric redmouth bacterium, salmonid kidney disease bacterium, viral hemmorrhagic septiicemia virus, infectious hematopoetic necrosis virus, and infectious pancreatic necrosis virus. Sex determination, total length measurements (to the nearest 1 mm), and weight (to the nearest 2 g) were recorded for 31 trout in the disease sample.

Sperm collections were conducted by personnel from the Jackson National Fish Hatchery (NFH) on 24 September. Ripe males among the disease sample were included in the sperm collection. Sperm was transported to the hatchery to fertilize females of the Jackson NFH broodstock.

Results

All trout in the disease sample tested negative for the selected pathogens. Mean lengths of 24 males and 7 females from the disease sample were 439 and 429 mm, respectively, and the male:female ratio was 3.4:1. Mean length for the combined sample was 436 mm. Difference in mean weight between males (655 g) and females (577 g) was not statistically significant ($\alpha=0.05$).

Sperm was collected from 35 males in 1986. A total of 292,400 eggs from the Jackson NFH broodstock (Jenny Lake strain) were fertilized on 25 September. Eye-up was approximately 34%, yielding 98,916 eyed eggs. All of these eggs were shipped to Allegheny NFH for eventual planting into Lake Ontario.

Discussion

Collection of a sufficient number of ripe females is still the most difficult part of the lake trout spawn-taking operation on Lewis Lake. Limiting collections to ripe males greatly reduces field time necessary to complete the operation. Since females in the Jackson NFH came from Jenny Lake (the result of another planting of fry from Lewis Lake), the resulting fry should enhance restoration attempts in the Great Lakes. In 1986, males of the Jackson NFH broodstock which originated from Lewis Lake in 1982 were available for production. They were crossed with females from the Jenny Lake strain. Approximately 1.1 million eyed eggs were produced from these crosses. The Wisconsin Department of Natural Resources received 105,176 eyed eggs; the remainder were shipped to Allegheny NFH, Iron River NFH, and Pendills Creek NFH (447,210, 412,384, and 127,296 eyed eggs, respectively). Females from the Lewis Lake broodstock should be available for production in 1987.

NONCONSUMPTIVE USE OF THE AQUATIC RESOURCE

In Yellowstone National Park there are presently two sections of the Yellowstone River which are closed to angling for the protection of spawning trout. These closed areas yield an excellent opportunity to study the level of visitation to aquatic habitats which are available only to nonangling uses, such as wildlife photography or viewing.

Fishing Bridge spans the Yellowstone River at the outlet of Yellowstone Lake; the area from the lake to a point 1.6 km downstream of the bridge has been closed to fishing since 1973. Although once very popular with anglers, Fishing Bridge was not considered a high quality fishery. Average landing rate for 1963 (Sharpe 1964) was 0.20 trout/hour, varying from a high of 0.48 during the first week of July to a low of 0.00 trout/hour during the first week of September. In 1966, Sharpe and Arnold (1967) reported that the catch per unit effort was lower than most park waters. Dean and Varley (1973) concluded that few anglers returned to the bridge after an initial experience because of crowding and low success rates.

LeHardy Rapids, located approximately 5.7 km downstream from the lake on Yellowstone River, has been closed to fishing for 90 m upstream and downstream from the rapids since 1949. During high water (May through July) fish congregate near the west bank in pools immediately below the rapids. From here the fish jump the rapids, often having to make several attempts, providing an extraordinary sight for the visitor. In 1984, a new boardwalk and viewing platform were constructed at LeHardy Rapids to facilitate visitor access and prevent continued erosion of the trail to the rapids. A sign identifying LeHardy Rapids was placed at the vehicle pullout in 1985.

Effects of angling closures were monitored at Fishing Bridge and LeHardy Rapids for the ninth consecutive year in 1986. Visitor use and mean length of stay were estimated at both areas.

METHODS

Since effort available for counts was limited, a "time available" method (Mathisen 1949; Bulkley 1966; Geiger 1972; Brown 1978) of data collection was employed. Instantaneous counts of visitors were made whenever possible at both Fishing Bridge and LeHardy Rapids, usually while en route to a work site. The location of project activities affects sampling effort at each site; therefore, sample size varies between years. In 1986, both ranger and naturalist employees also made counts at both sites; their participation helped to increase the number of observations.

Critical aspects of this method are accurate estimates of average time spent per person and daily use pattern. Accuracy increases as the number of time intervals increase; however, if interval sizes become too small, the increase in time periods without counts causes a decrease in the resulting estimate. Using these criteria, a 15-minute time interval appears to be optimum for Fishing Bridge and LeHardy Rapids use estimates.

A daily use curve was determined by averaging all counts for each interval. Total visitor hours for each interval were then calculated using the following formula:

> Effort (visitor hours) = $1/2\ I(t_i + t_{i+1})$, where I is the time interval, and t_i is the mean number counted at interval i.

To obtain a daily total for visitor hours, instantaneous counts were expanded by the proportion of daily use represented by each time interval. On days when more than one count was made, the mean number of visitor hours was used. Total number of visitors for each day was obtained by dividing visitor hours by the mean length of stay. Season totals were calculated by summing daily totals and then expanding by the proportion of days actually counted.

RESULTS

In 1986, mean length of stay at Fishing Bridge for 1,158 people was 9.2 minutes/person. Total number of visitors increased from 1984 (approximately 19%) to 188,674 visitors. Total visitor hours decreased (approximately 15%) from 1985 to 28,773 hours (Table 43).

Mean length of stay at LeHardy Rapids was 8.15 minutes/person in 1986 (n=2,155). Total number of visitors was estimated to be 217,371 people, and total time spent at the rapids was 29,454 hours. Both values are the highest ever reported for LeHardy Rapids nonangler use.

Table 43. Nonconsumptive use of the aquatic resource, 1978-86.

	Year	Number of Counts	Total Number of Visitors	Mean Minutes per Person	Total Visitor Hours
Fishing Bridge					
	1978	582	132,966	10.8	23,934
	1979	670	170,383	-	30,669
	1980	551	130,305	10.7	23,238
	1981	1,015	173,679	12.3	35,604
	1982	425	167,333	9.7	26,941
	1983	421	208,672	-	33,580
	1984	430	178,009	10.7	31,686
	1985	253	158,360	12.8	33,915
	1986	587	188,674	9.2	28,773
LeHardy Rapids					
	1978	222	17,287	8.4	2,420
	1979	206	17,627	-	2,798
	1980	94	45,610	5.3	4,029
	1981	155	12,056	16.2	3,255
	1982	154	26,768	8.1	3,600
	1983	93	12,245	-	1,647
	1984	131	20,718	-	2,787
	1985	212	185,467	5.1	15,827
	1986	286	217,371	8.2	29,454

Table 44. Fishing Bridge creel census data, 1965-72.

Year	Total Anglers	Total Hours
1965	41,387	41,387
1966	30,135	30,135
1968	40,153	40,262
1970	25,699	31,644
1972	22,824	38,079

DISCUSSION

Creel census data for the last 8 years (1965-72) of angling on Fishing Bridge yielded an average of 33,275 total anglers and 36,714 total angler hours/year (Table 44). While the 1986 nonconsumptive use figures represent slightly lower total hours on Fishing Bridge, the number of people enjoying this area has increased almost 400% since the bridge was closed to fishing; concomitantly, park visitation has only risen approximately 16%.

Visitor use at LeHardy Rapids increased phenomenally in 1985, but current levels of use are even higher, approximately 10 times greater than the mean for the 7 years prior to 1985. The number of visitors at LeHardy Rapids in 1986 exceeded Fishing Bridge estimates for all years (Table 43).

Jones et al. (1985) suggested that the boardwalk completed late in 1984 might attract a larger number of visitors to LeHardy Rapids in future years. The boardwalk undoubtedly contributed to current visitation in the area; however, the addition of the location sign may actually have had a greater affect on use in the area. The rapids are not visible from the road, and although access was improved by the boardwalk, it was also difficult to see from passing cars. The sign identifies the location and signifies an area of interest to the park visitor.

It is difficult to explain the difference in the number of visitors at LeHardy Rapids and Fishing Bridge. If the number of people traveling past LeHardy Rapids is greater, then the addition of the location sign may account for the inequality.

Comparing nonangler use to park fisheries, more people utilize either Fishing Bridge or LeHardy Rapids than any single fishery in the park (Tables 5 and 43). LeHardy Rapids ranks sixth and Fishing Bridge seventh when compared, in terms of total hours, to angler effort among park fisheries.

Estimates of nonangler use during the past 9 years emphasize the value of these viewing sites and the demand for this type of visitor activity. Observing the interactions of fish in their natural habitat, including reproduction and feeding, is truly an educational experience for anglers and nonanglers alike.

TECHNICAL PAPERS

The project has started a series of numbered technical reports which are published separate from this annual progress report. Additionally, several papers are generally published each year which appear in other reference sources. Abstracts of these reports and papers which were completed during the current year are reported in this section.

Ewing, R., J. Mohrman, and D. Carty. 1986. Sources and quantities of suspended sediment in the Yellowstone River and selected tributary watersheds between Yellowstone Lake outlet, Yellowstone National Park, Wyoming, and Livingston, Montana: 1985 Annual Progress Report. U.S. Fish and Wildlife Service. Yellowstone Fisheries Assistance Office. Aquatic Ecology Studies: Technical Report Number 2. Yellowstone National Park, Wyoming, USA.

This study was initiated in 1985 to investigate sources and quantities of suspended sediment and turbidity in the Yellowstone River and major tributary watersheds from Yellowstone Lake outlet, Yellowstone National Park, Wyoming, downstream to Livingston, Montana. Data collected were related to precipitation, stream flow, suspended sediment, and turbidity. During the 1985 water year, precipitation in the study area was slightly less than average in the winter (October 1984-March 1985) and snowmelt (April 1985-June 1985) months, and somewhat greater than normal in the summer (July 1985-September 1985) season. Highest levels of streamflow, suspended sediment, and turbidity in the Yellowstone River occurred during the snowmelt period. In summer, times of relatively high streamflows, suspended sediment, and turbidity were associated with rain events. Transit times of water surges (and by association, sediment plumes) between Tower Junction, Yellowstone National Park, and Livingston, Montana, ranged from 24-28 h. The Lamar River drainage was the tributary watershed which had the greatest influence on the streamflow, suspended sediment, and turbidity of the Yellowstone River. Other tributary watersheds, notably the Gardner River and Tom Miner Creek drainages, also affected the amounts of suspended sediment and turbidity in the Yellowstone River during snowmelt and during rain events in summer.

Gresswell, R.E. In Press. Special regulations as a fishery management tool in Yellowstone National Park. Proceedings of the second Science in the Parks Conference, July 1986.

Given National Park Service policy and increasing angler use, restrictive angling regulations have become the most successful method of accomplishing fishery management objectives in Yellowstone National Park. Species and habitat differences greatly affect results of these regulations. Vulnerable native species such as cutthroat trout (*Salmo clarki*) and grayling (*Thymallus arcticus*) have responded positively to catch-and-release-only (no-kill) regulations in all cases. A 330-mm *maximum* size limit has also worked well for cutthroat trout in Yellowstone Lake, but the same regulation failed on Riddle Lake where population structure and habitat were significantly different. Although restrictive regulations have improved population structure for brown trout (*Salmo trutta*), landing rates have remained low. Brown trout apparently have an extremely low catchability where secure habitat is abundant. Brook trout (*Salvelinus fontinalis*) seem to be limited by nutrient-poor conditions in most park waters, but the use of a *maximum* size limit has been proposed to protect populations inhabiting waters which produce large individuals.

Gresswell, R.E., and J.D. Varley. 1986. Effects of a century of human influence on the cutthroat trout of Yellowstone Lake. Pages 36-46 *in* J.S. Griffith, editor. The ecology and management of interior stocks of cutthroat trout. Special publication of the Western Division, American Fisheries Society.

Over the past century, man has had an adverse impact on the cutthroat trout (*Salmo clarki bouvieri*) of Yellowstone Lake. Direct effects have included introduction of exotic species, hatchery operations, and angler harvests. Thus far it appears that hatchery operations and harvest by anglers have been the most deleterious.

Three nonnative fishes introduced to the system have apparently filled empty niches in the lake ecosystem, and there is no evidence of direct competition between these nongame fish and native cutthroat trout. Potential competition from introduced nonnative brook trout (*Salvelinus fontinalis*) was thwarted by chemical removal of this species from Arnica Creek, a tributary to Yellowstone Lake. Although egg-taking and hatchery operations were terminated over 30 years ago, it is now apparent that egg removal, genetic mixing, and greatly reduced natural spawner escapement led to a gradual reduction in reproductive potential and undermined the complex mosaic of reproduction and recruitment. Angler harvest also had a significant negative impact when it became excessive. During the past decade, increasingly restrictive regulations have helped to restore population numbers and age-class structure. Current policies which prohibit exotic species introduction, rely on natural wild stocks, and restrict angler harvests are products of continued effort to manage the lake as an ecological unit.

Jones, R.D., and L.D. Lentsch. In press. Yellowstone National Park's maintenance of genetic diversity among native and nonnative salmonids. Proceedings of the second Science in the Parks Conference, July 1986.

This paper describes selected species of salmonids, including several unique strains, in Yellowstone National Park and discusses their cultural, scientific, and management values. Salmonids native to the park include the Montana grayling (*Thymallus arcticus montanus*), mountain whitefish (*Prosopium williamsoni*), and two subspecies comprising four strains of cutthroat trout (*Salmo clarki*). Approximatley 40 percent of the waters were fishless when the park was established in 1872. Four nonnative species (brown trout, *Salmo trutta*; rainbow trout, *S. gairdneri*, brook trout, *Salvelinus fontinalis*; and lake trout, *Salvelinus namaycush*) were subsequently introduced into fishless waters, and in many cases, into waters harboring indigenous populations. For nearly a century, park managers have protected distinctive ecotypes of salmonids, including both native and nonnative species. This has produced many tangible benefits including (1) maintenance of genetic diversity in unique salmonid stocks, (2) recovery of depressed trout populations both inside and outside of the park, and (3) enhancement of sport fishing opportunities in Yellowstone National Park, and elsewhere throughout the western United States. The present goals of the fishery management in Yellowstone National Park are to manage fish populations and their habitats as functioning components of the greater Yellowstone ecosystem, and preserve and restore native species and aquatic habitats.

Mahony, D.L. 1987. Aquatic resource inventory and fisheries habitat assessment in Reese Creek, Yellowstone National Park. U.S. Fish and Wildlife Service. Yellowstone Fisheries Assistance Office. Aquatic Ecology Studies: Technical Report Number 3. Yellowstone National Park, Wyoming, USA.

Reese Creek is the only stream in Yellowstone National Park that is periodically dewatered by private landowners for irrigation purposes. To investigate potential impacts of dewatering on fish habitat and trout spawning, an aquatic resource inventory and habitat assessment were conducted on Reese Creek from May through August 1986. Weekly electrofishing surveys were used to determine whether a spawning migration of trout from the Yellowstone River occurred in Reese Creek. Natural and diverted streamflows were monitored throughout the study period.

With the exception of the portion of Reese Creek subject to dewatering, fisheries habitat was rated as moderately high quality. Cutthroat trout (Salmo clarki), rainbow trout (Salmo gairdneri), and rainbow x cutthroat trout hybrid of Yellowstone River origin spawned in Reese Creek from late May through mid-July 1986. Brown trout (Salmo trutta), brook trout (Salvelinus fontinalis), and mottled sculpin (Cottus bairdi) were also captured.

Major dewatering of Reese Creek coincided with spawning migration, and as much as 91% of the streamflow was diverted during the spawning run. Reese Creek was totally dewatered 2 weeks after the peak migration. As a result of dewatering, successful incubation, hatching, emergence, and rearing of trout fry in Reese Creek, as well as emigration of fry to the Yellowstone River appears to be negligible. Since there are only a limited number of spawning tributaries in the upper Yellowstone River, it is concluded that streamflow withdrawals in Reese Creek may have a negative impact on the Yellowstone River trout fishery.

Schill, D.J, J.S. Griffith, and R.E. Gresswell. 1986. Hooking mortality of cutthroat trout in a catch-and-release segment of the Yellowstone River, Yellowstone National Park. North American Journal of Fisheries Management 6:226-232.

Hooking mortality was examined in a population of wild cutthroat trout (Salmo clarki bouvieri) in a portion of the Yellowstone River, Yellowstone National Park, which is managed under catch-and-release regulations. The number of trout dying from capture and release in the 4.5-km study area was assessed by searching for trout carcasses in established snorkeling routes. We divided our estimate of angler-induced mortalities by cutthroat trout abundance and creel survey data to estimate single capture hooking mortality and exploitation rates resulting from catch-and-release angling in the study area. The average number of times cutthroat trout were recaptured during the study period was estimated from the results of the creel survey and cutthroat trout abundance data. The hooking mortality rate per single capture was 0.3%. In 1981, 3% of the estimated cutthroat trout population died after capture and release by anglers. Cutthroat trout in the study area were captured an average of 9.7 times during the study period in 1981.

OTHER PROJECT ACTIVITIES

Assistance to Independent Researchers

Yellowstone National Park is the largest intact ecosystem in the temperate zone of the earth, 890,000 hectares of near pristine wilderness. The park was designated a biosphere reserve in 1976 and contains some of the most diverse geothermal, geological, and biological features in the world. Scientists are recognizing the critical role of natural systems in political, economic, and social problems of the world and are coming to Yellowstone National Park in increasing numbers to study its natural systems.

The Yellowstone fishery project functions as an administrative liaison and provides logistical support to independent researchers working on aquatic-related studies in Yellowstone National Park. Project personnel work closely with researchers in order to facilitate an economical and timely completion of research in the park. Project equipment, manpower, and facilities are provided without compensation for small studies, and on a reimbursable basis for larger ones.

In 1986, the project provided assistance to Stephen Klein, a Ph.D. candidate of the Civil and Enviromental Engineering School at the University of Colorado. Steve is performing a study entitled "Environmental Assessment of Heavy Metal Contamination in Yellowstone National Park". The objective of the research is to define the level of heavy metal contamination in aquatic habitats within the park through a combined analyses of environmental transport, bioaccumulation, and enviromental chemistry. This study will provide detailed analysis and assessment of contamination and its significance to the health of aquatic environments and park visitors.

The project provided laboratory space, boats, and 6 man-days of assistance to Jerry Kaster of the University of Wisconsin-Milwaukee Center for Great Lake Studies. This research, "The Study of Substrate Characterization of Retrogressive Oligothrophy in Yellowstone Lake", will attempt to determine if Yellowstone Lake is becoming more oligotrophic, by investigating the bottom sediments.

The project provided Fred Binkowski of the University of Wisconsin-Milwaukee Center for Great Lake Studies with laboratory space, boats, equipment, and 3 man-days of personnel assistance. Mr. Binkowski is studying the life history of lake trout in Lewis Lake.

The project provided assistance to Val J. Klump, Univeristy of Wisconsin-Milwaukee Center of Great Lakes Studies with laboratory space, boats, and equipment. Mr. Klump is studying sub-lacustrine fumarole communities in Yellowstone Lake.

Assistance was provided to Dave Blackwell, Department of Geological Sciences, Southern Methodist University, Dallas, Texas. The project provided a 30-foot research vessel (Cutthroat), laboratory and shop space, and 10 man-days of personnel assistance in support of his 6-week project. Dr. Blackwell's research "Heat Flow in Yellowstone Lake" involves a completed detailed heat flow study of the lake. This is accomplished by droping a probe into the lake sediments and recording temperature gradients. The purpose of the study is to study the mechanisms of cooling of large silica batholiths and the characteristics of large-scale geothermal systems associated with such batholiths.

The project provided assistance to R.O. Fournier of the U.S. Geological Survey with water chemisty data on the aquatic systems of Yellowstone. Mr. Fournier is assisting with an aquatic classification of the waters in Yellowstone based on chemical analysis of water samples.

The project provided assistance to Chris Clancy of the Montana Department of Fish, Wildlife, and Parks in collecting spawning migration data on the Gardner River. The study was designed to investigate spawning migrations of brown trout, cutthroat trout, rainbow trout, and rainbow x cutthroat trout hybrids from the Yellowstone River into the Gardner River.

The project provided assistance to Mark J. Rosenfeld, of the Univeristy of Utah, with fish collections in Yellowstone Park. The collections involved project equipment and 10 man-days of personnel assistance. Mr. Rosenfeld is studying "The Genetics and Biogeography of Western North American Fishes".

The project provided data and planning assistance to H.E. Wright of the University of Minnesota for his study of "The Relationship of Climate to Sedimentation Rates in Lakes and Ponds in Yellowstone National Park".

The project provided laboratory space to Lewis T. Nielsen of the Univeristy of Utah for his study on "Biological Control of Mosquitoes with Mermithid Nematode Parasites".

The project provided Bruce Roberts of Montana State University with 3 man-days of assistance collecting cutthroat trout eggs for use in his study on "Potential Influence of Recreational Use on Cutthroat Embryo and Pre-emergent Fry".

Information Distribution

Information produced by the Yellowstone Fishery and Aquatic Management Program is made available to the scientific field and the general public in several ways. The annual fishery and aquatic management program technical report has a distribution of approximately 130 copies annually.

The project receives 50-100 information requests each year by phone or mail. Response time on these requests requires from 10 minutes to an hour on the phone to several days on a research request.

Project personnel are also very active in the American Fisheries Society and other fishery organizations. In 1986, papers were given at the Western Division of the American Fishery Society and the Montana Chapter of the American Fishery Society. Four poster sessions were presented at the National Park Service Science Conference. One symposium was presented at Montana State Univeristy. Presentations were also made to the Gardiner Fly Fishers, Gardiner, Montana, and a citizens group in Waldron, Arkansas. Project personnel also provide training to National Park Service ranger and naturalist staff on fisheries management in Yellowstone Park.

Volunteer Program

Volunteer programs of the Fish and Wildlife Service, the National Park Service, and the Student Conservation Association have been utilized for many years. The program provides a needed manpower source for the project and a valuable training experience for the volunteer. In 1986, the project utilized 170 man-days of volunteer work and 122 man-days of student conservation association work. These volunteers were involved in all phases of project work including angler interviews, gillnetting, electrofishing, backcountry stream and lake surveys, and a variety of clerical and maintenance jobs. The effort and dedication of these volunteers is very important to the Yellowstone fishery program.

Youth Conservation Corps

The Yellowstone Fishery Project had its own Youth Conservation Corp (YCC) program in 1986. The project had four enrollees which provided 160 man-days of work to the project. These enrollees were involved in many aspects of project activities, including backcountry stream surveys, angler interviews and counts, fish population sampling, and maintenance. The enrollees were also involved in National Park Service activities such as naturalist programs, working in visitor centers and some aspects of the ranger operation. The YCC enrollees efforts were important to the Fish and Wildlife Service, the National Park Service, and provided a valuable educational experience for the enrollees. The project also utilized 35 man-days of National Park Service YCC labor in the repair of the Clear Creek fish trap.

The Yellowstone fishery project would not be able to function at its present level with out the volunteer programs. In 1986, 292 man-days of labor was provided by volunteers. At minimum wage, it was worth $8,176.00 to the project.

ACKNOWLEDGMENTS

Our sincere thanks to those who assisted the project during the past year. Karl Biastoch and Glenn Boltz were critical to our summer field program as paid seasonals; both returned as part-time volunteers in the winter. Jay Thompson and Jane Wallace, members of the Student Conservation Association program, worked as full-time volunteers during the summer field season. Although not participating on a full-time basis, Marion Jones volunteered her time whenever possible. Liz Colvard and John Dinice provided assistance on several important projects. Crystal Hudson, a permanent staff member, served as the project administrative assistant and as an experienced member of the field crew; Crystal also participated in the preparation of this report and authored the LeHardy Rapids section of the report. Karrie West, now after 7 years a permanent project employee (congratulations, Karrie), entered data from field forms into the computer, prepared tables and figures, and typed the manuscript; we deeply appreciate her efficiency and patience. Kim West converted the VAR cards into data on computer tapes. Jack Brooks and Wade Miller returned for the annual fall gillnetting; Wade helped with the nets, and Jack prepared gourmet meals for the crew. George Roemhild provided the expertise for identification of macroinvertebrate samples, and personnel from the Jackson National Fish Hatchery expedited lake trout spawn-taking at Lewis Lake.

The National Park Service (NPS) also provided manpower assistance in 1986. Roy Ewing and Jana Mohrman were the backbone for the Yellowstone River Sediment Study. Ann-Marie Chytra, the Heart Lake Ranger, again served as "resident limnologist" at Heart Lake. Brian O'Dea, ranger at Northeast Entrance, collected macroinvertebrate samples from Soda Butte Creek. Rangers from the Snake River District (Dirk Choufant, Collette Daigle-Berg, Les Inafuku, and Doug Ridley) assisted in the Heart Lake and Yellowstone Lake spawning surveys, and other rangers conducted angler surveys at park entrances.

Thanks also to the 35-odd individuals who participated in the Arnica Creek restoration project. Bruce Roselund and Bill Mytton of the USFWS provided valuable guidance during planning and field operations. Other personnel were "on loan" from the NPS (Administration, Ranger Division, Research Division), Interagency Grizzly Bear Study Team, and the Yellowstone Lake Hospital.

Again, we appreciate the help of all of those above and also to those who contributed but have not specifically been mentioned.

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APPENDIX A

Appendix Table 1. Gillnet catches of cutthroat trout by site, Yellowstone Lake, 1969-72, 1974, 1976-80, and 1982-86[a].

	Number per net[b]											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Total
1969	3	19	5	17	5	c)	c)	3	28	14	16	110
1970	10	18	10	11	15	20	9	2	32	7	1	135
1971	15	5	23	21	8	c)	c)	c)	c)	c)	c)	72
1972	15	13	21	16	12	17	3	9	19	8	17	150
1974	11	12	25	21	26	6	12	19	12	6	20	170
1976	19	9	22	11	21	19	15	13	10	12	14	165
1977	10	23	15	16	21	19	12	7	15	12	22	682
1978	14	9	15	10	17	16	14	15	18	13	13	766
1979	12	18	12	10	9	19	12	16	18	12	10	748
1980	7	21	17	6	14	12	12	13	18	15	9	715
1982	12	10	9	8	11	11	11	8	12	10	12	582
1983	23	18	24	16	22	22	13	18	14	14	13	993
1984	25	16	23	16	32	17	20	14	15	16	21	1053
1985	14	15	19	1	13	23	13	23	12	16	9	784
1986	14	26	23	9	20	18	7	15	24	13	15	921

	Average total length (mm)											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Average
1969	277	293	322	328	378	c)	c)	360	290	341	300	311
1970	290	308	327	365	279	352	352	352	280	364	224	315
1971	291	363	306	326	379	c)	c)	c)	c)	c)	c)	321
1972	297	293	262	329	321	296	368	358	334	349	329	313
1974	249	330	304	300	266	284	311	290	301	348	324	298
1976	315	322	306	337	291	302	324	331	324	330	337	317
1977	301	261	305	290	286	265	341	283	269	344	292	290
1978	286	327	281	313	298	293	319	286	302	342	365	308
1979	276	281	312	322	306	280	306	288	294	374	335	303
1980	279	302	310	344	309	308	341	268	286	339	345	309
1982	276	280	342	345	306	274	356	324	358	362	327	322
1983	256	276	263	297	290	249	328	276	324	353	323	288
1984	263	317	298	271	239	259	306	282	325	307	271	281
1985	297	296	323	327	297	275	353	274	331	362	355	311
1986	288	268	328	317	260	291	327	274	265	338	328	293

	Average weight (g)											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Average
1969	213	272	317	359	527	c)	c)	411	261	403	249	312
1970	311	279	348	450	223	382	390	320	349	488	108	320
1971	249	363	267	318	452	c)	c)	c)	c)	c)	c)	305
1972	269	276	231	350	352	262	410	405	358	459	349	320
1974	167	341	267	269	200	253	290	265	285	361	309	266
1976	322	337	280	363	267	285	322	331	306	353	358	314
1977	273	214	292	268	258	219	399	256	215	430	270	271
1978	254	360	235	336	292	283	337	260	290	416	497	316
1979	222	245	316	339	300	239	304	255	280	517	400	301
1980	357	302	316	418	314	309	410	217	255	430	414	329
1982	233	240	403	406	319	239	470	369	455	471	360	359
1983	188	226	216	294	272	168	375	248	347	455	378	271
1984	199	399	250	244	165	191	318	250	354	375	227	259
1985	281	280	344	343	279	234	470	237	365	524	458	332
1986	242	208	354	313	194	264	365	220	207	414	391	274

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a) Experimental gillnets (38.1 m long) set overnight (7.6 graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5-4.6 m depth interval.

b) From 1969-76, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets, and 1978-86 represents an average of 5 sets.

c) Areas not sampled.

Appendix Table 2. Gillnet catches of cutthroat trout by general area, Yellowstone Lake, 1969-72, 1974, 1976-80, and 1982-86[a].

Year	Number/net				Average total length (mm)				Percentage under 210 mm				
	North	Central	W. Thumb	South	North	Central	W. Thumb	South	North	Central	W. Thumb	South	Total
1969	10	--	16	15	316	--	296	319	12.2	--	9.7	10.0	10.9
1970	13	14	17	4	311	352	285	346	7.8	0.0	17.6	0.0	8.1
1971	14	--	--	--	321	--	--	--	1.4	--	--	--	1.4
1972	15	10	14	12	297	307	342	336	11.7	0.0	0.0	4.0	6.7
1974	19	9	16	13	289	302	294	329	14.7	16.7	25.8	0.0	14.7
1976	16	17	13	13	310	311	328	333	11.0	5.9	4.3	7.7	8.5
1977	17	15	11	17	284	293	273	309	28.2	23.1	30.3	13.3	24.6
1978	13	15	17	13	298	305	294	353	13.2	8.6	5.4	0.8	8.5
1979	12	15	17	11	297	290	291	356	18.1	21.0	14.5	6.1	16.0
1980	13	12	15	12	307	325	278	341	14.0	11.0	16.0	11.0	13.4
1982	10	11	10	11	307	316	341	342	15.7	15.0	6.9	4.5	11.9
1983	21	18	16	14	275	278	297	339	26.4	21.6	13.7	8.0	20.9
1984	22	19	15	18	272	286	304	286	30.3	18.0	12.4	24.2	24.8
1985	12	18	17	12	305	303	294	360	11.3	20.8	16.4	5.7	13.7
1986	18	13	20	14	289	301	268	332	22.4	19.8	27.0	12.1	21.5
Averages	15	15	15	13	292	300	293	332	20.0	17.0	15.4	9.8	17.0

a) Net locations as follows: North - 1A, 1B, 1C, 2A, 2B; Central - 3A, 3B; W. Thumb - 4A, 4B; South - 6C, 7C.

Appendix Table 3 . Gillnet catches of longnose sucker by site, Yellowstone Lake 1969-72, 1974, 1976-80, and 1982-86[a].

	Number per net[b]											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Total
1969	7	28	39	13	31	c)	c)	5	1	1	22	147
1970	13	3	4	23	16	3	1	4	3	0	1	71
1971	17	75	7	13	73	c)	c)	c)	c)	c)	c)	185
1972	4	4	0	3	2	0	0	3	2	5	5	28
1974	27	26	15	9	26	6	18	5	17	4	22	175
1976	13	30	13	26	13	8	14	13	14	0	16	160
1977	9	3	8	14	13	4	8	4	8	0	10	319
1978	4	18	7	11	13	6	3	5	9	1	2	398
1979	18	21	11	18	23	5	13	6	12	5	7	695
1980	5	12	9	15	13	2	15	5	17	6	11	548
1982	15	21	8	12	15	17	19	7	20	8	3	726
1983	14	24	8	11	16	11	8	7	13	7	4	625
1984	17	11	11	21	26	12	6	13	12	11	11	737
1985	8	6	4	5	18	4	6	8	5	0	4	342
1986	9	19	5	20	27	1	7	4	17	4	2	569

	Average total length (mm)											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Average
1969	431	319	411	394	323	c)	c)	368	425	360	358	365
1970	444	392	427	380	415	425	306	376	317	---	214	393
1971	432	267	433	410	312	c)	c)	c)	c)	c)	c)	316
1972	446	291	---	242	318	---	---	422	358	330	290	335
1974	401	340	428	401	345	392	355	385	358	369	356	370
1976	427	334	414	408	394	396	373	411	385	---	398	389
1977	440	408	434	407	413	380	361	400	431	---	409	401
1978	437	353	424	412	307	354	329	409	321	285	338	363
1979	435	342	429	413	334	396	325	397	345	285	362	371
1980	422	330	428	410	360	402	322	416	312	300	414	365
1982	438	363	432	400	323	374	316	414	289	261	401	356
1983	416	298	436	410	300	382	337	377	298	254	236	341
1984	407	311	410	339	283	382	385	340	361	266	443	349
1985	420	407	421	414	299	319	327	395	325	---	417	362
1986	406	388	416	314	276	370	323	389	332	265	330	334

	Average weight (g)											
	1a	1b	1c	2a	2b	3a	3b	4a	4b	6c	7c	Average
1969	938	415	855	825	434	c)	c)	621	860	614	592	635
1970	1076	971	970	773	883	1003	366	692	367	---	112	838
1971	963	273	935	869	413	c)	c)	c)	c)	c)	c)	459
1972	1012	260	---	167	575	---	---	961	600	457	286	519
1974	804	561	952	774	574	775	546	790	367	646	577	668
1976	930	527	951	834	560	765	651	876	720	---	806	759
1977	995	847	1047	840	898	716	656	810	529	---	889	833
1978	992	594	913	899	423	593	478	859	467	304	595	654
1979	986	567	964	864	563	791	484	810	552	339	689	699
1980	929	502	957	848	657	777	468	855	429	346	885	660
1982	970	662	931	852	478	701	451	911	324	249	928	631
1983	935	442	1042	898	415	743	524	759	361	211	234	596
1984	331	397	385	574	265	753	580	701	574	263	1077	500
1985	947	870	990	932	393	493	504	888	480	---	997	688
1986	804	733	906	423	285	787	457	734	491	241	575	516

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a) Experimental gillnets (38.1 m long) set overnight (7.6 graduated mesh panels 19, 25, 32, 38, and 51 mm) in the 1.5-4.6 m depth interval.

b) From 1969-76, only 1 set was made in each area at the specified depth interval; for 1977, the number represents an average of 4 sets, and 1978-86 represents an average of 5 sets.

c) Areas not sampled.

Appendix Table 4. Stream names/numbers used to identify Yellowstone Lake tributaries between Lake Area and Grant Village, 1974-86.

General Location	Revised SONYEW Number (1986)	Original SONYEW Number (1976-85)	Name or Hoskin's number (1974-75)
Lake Area	1203	0271	111
	1202	0270	Hotel Creek (110)
	1201	0269	Hatchery Creek (11)
Lake Area to Rock Point	1200	0268	12
	1199	0267	13
	1198	0266	Wells Creek (14)
	119701	0265	15
	1197	0260	Bridge Creek
	1196	0259	17
	1195	0258	16
	1194	0257	18
	1193	0256	19
	1192	0255	Weasel Creek
	1191	0252	42
Rock Point to Pumice Point	1190	0251	20
	1189	0250	21
	1188	0249	22
	1187	0248	23
	1186	0247	24
Pumice Point to Grant Village	1185	0239	26
	1184	0238	25
	1183	0235	Arnica Creek
	1182	0234	Little Arnica Creek (27)
	1181	0233	28
	1180	0232	29
	1179	0231	30
	1178	0230	31
	1177	0229	32
	1176	0228	Little Thumb Creek
	1175	0227	-
	1174	0226	33
	1173	0225	34
	1172	0222	-
	1171	0221	-
	1170	0220	35
	1169	0219	36
Grant Village	1168	0218	Big Thumb Creek
	1167	0217	37
	1166	0216	Sandy Creek (38)
	1165	0215	39
	1164	0214	Sewer Creek (40)

Appendix Table 5. Yellowstone Lake tributaries between Lake Area and Grant Village not found by the study team in 1986 (Revised SONYEW numbers and/or names only).

Stream Number	Stream Name
1191	-
1175	-
1172	-
1171	-
1170	-

Appendix Table 6. Yellowstone Lake tributaries between Lake Area and Grant Village where no spawning was observed in 1986 (Revised SONYEW numbers and/or names only).

Stream Number	Stream Name	Reason for no Spawning[a)]
1202	Hotel Creek	D
119701	-	A
1196	-	A
1195	-	A
1194	-	A
1193	-	A
1190	-	A
1189	-	B
1188	-	A
1187	-	A
1186	-	A
1185	-	A
1184	-	U
1181	-	A
1178	-	B
1174	-	B,C
1173	-	B,C
1165	-	A

a) Reason for no spawning:
A = Judged unsuitable by study team (n=12)
B = Natural physical barrier at stream mouth (n=4)
C = Apparent chemical barrier (n=2)
D = Man-made physical barrier (n=1)
U = Unknown (n=1)

Appendix Table 7. Yellowstone Lake tributaries not found in 1985 or 1986.

Stream Number	Stream Name
1191	-
1175	-
1172[a)]	-
1171[a)]	-
1170[a)]	-
1149	-
1139	-
1133	-
1117	-
1116	-
1112	-

a) Jones et al. (1986) assumed these streams existed and reported them as nonspawning streams because they drained portions of Potts Hot Spring Basin and West Thumb Geyser Basin; however, efforts to locate them in 1986 were not successful.

Appendix Table 8. Yellowstone Lake tributaries not annually used as spawning streams.

Stream Number	Stream Name
1192	Weasel Creek
1189	-
1187	-
1165	-
1162	-
1151	-
1148	-
1147	-
1143	-
1139[a)]	-
1137	-
1132	-
1130	-
1109	-
1106	-
1101	-

a) Reported as a spawning stream by Hoskins (1974), but not found by USFWS or IGBST in 1985 or 1986.

Appendix Table 9. Yellowstone Lake tributaries between Lake Area and Grant Village where spawning was observed in 1986 (Revised SONYEW numbers and/or names only).

Stream Number	Stream Name	Was stream sampled?	If not sampled, why not?[a]
1203	-	Yes	
1201	Hatchery Creek	Yes	
1200	-	Yes	
1199	-	Yes	
1198	Wells Creek	Yes	
1197	Bridge Creek	Yes	
1192	Weasel Creek	Yes	
1183	Arnica Creek	No	A
1182	Little Arnica Creek	Yes	
1180	-	Yes	
1179	-	Yes	
1177	-	Yes	
1176	Little Thumb Creek	Yes	
1169	-	Yes	
1168	Big Thumb Creek	Yes	
1167	-	Yes	
1166	Sandy Creek	Yes	
1164	Sewer Creek	Yes	

a) If not sampled, why not?
A = Stream too large to be sampled with backpack electrofishing gear.

Appendix Table 10. Mean total lengths of cutthroat trout captured in the Yellowstone River, 1952-86.

		Mean total length in mm (inches)				Sample		
Regulations	Year	Dip net	Electrofishing	Hook and line	Creel	size	Area	Source
5 fish bag limit, no size limit	1952	368 (14.5)[a]				382	LeHardy Rapids	Cope 1953
					330 (13.0)	107	Above Upper Falls	Cope 1953
3 fish bag limit, no size limit	1967		345 (13.6)			346	Excluding Hayden Valley	Unpublished data
					338 (13.3)	127	Excluding Hayden Valley	Dean and Varley 1973
	1968		351 (13.8)			351	Excluding Hayden Valley	Unpublished data
					348 (13.7)	487	Excluding Hayden Valley	Dean and Varley 1973
3 fish bag limit, 14" minimum size limit	1970				378 (14.9)	43	Excluding Hayden Valley	Dean and Mills 1971
				424 (16.7)		17	Hayden Valley	Dean 1972
	1971		447 (17.6)			309	Hayden Valley	Dean 1972
			361 (14.2)			378	Fishing Bridge	Dean 1972
	1972				368 (14.5)	125	Excluding Hayden Valley	Dean and Varley 1973
	1973				363 (14.3)	2798	Above falls, excluding Hayden Valley	Jones et al. 1976
Catch and release	1974	362 (14.3)[a]				463	LeHardy Rapids	Dean et al. 1975
					372 (14.6)	3926	Excluding Hayden Valley	Dean et al. 1975
	1975	370 (14.6)[a]				775	LeHardy Rapids	Varley et al. 1976
					366 (14.4)	10540	Above falls, excluding Hayden Valley	Varley et al. 1976
	1976	375 (14.8)[a]				964	LeHardy Rapids	Jones et al. 1977
					373 (14.7)	11062	Above falls, excluding Hayden Valley	Jones et al. 1980
	1977	373 (14.7)[a]				245	LeHardy Rapids	Jones et al. 1978
					373 (14.7)	10239	Above falls, excluding Hayden Valley	Jones et al. 1980
	1978	376 (14.8)[a]				759	LeHardy Rapids	Jones et al. 1979
					382 (15.1)	8950	Above falls, excluding Hayden Valley	Jones et al. 1980
	1979	385 (15.2)[a]				571	LeHardy Rapids	Jones et al. 1980
					387 (15.2)	8495	Above falls, excluding Hayden Valley	Jones et al. 1980
	1980	384 (15.1)[a]				483	LeHardy Rapids	Jones et al. 1981
					390 (15.3)	7789	Above falls, excluding Hayden Valley	Jones et al. 1981
	1981	387 (15.2)[a]				571	LeHardy Rapids	Jones et al. 1982
			397 (15.6)			148	Cable Car Area	Jones et al. 1982
					392 (15.4)	9904	Above falls, excluding Hayden Valley	Jones et al. 1982
	1982	389 (15.3)[a]				694	LeHardy Rapids	Jones et al. 1983
					395 (15.6)	8746	Above falls, excluding Hayden Valley	Jones et al. 1983
	1983	394 (15.5)[a]				570	LeHardy Rapids	Jones et al. 1984
					398 (15.7)	9983	Above falls, excluding Hayden Valley	Jones et al. 1984
	1984	399 (15.7)[a]				526	LeHardy Rapids	Jones et al. 1985
					401 (15.8)	7567	Above falls, excluding Hayden Valley	Jones et al. 1985
	1985	401 (15.8)[a]				431	LeHardy Rapids	Jones et al. 1986
					401 (15.8)	6626	Above falls, excluding Hayden Valley	Jones et al. 1986
	1986	396 (15.6)[a]				596	LeHardy Rapids	Current Report
					394 (15.5)	6931	Above falls, excluding Hayden Valley	Current Report

a) Adults only.

Appendix Table 11. Beaver Creek water temperatures, 1986.

		Temperature (C)		
Date	Time	Mean	Maximum	Minimum
30 May	1600	12.7	14.4	3.3
31 May	1045	6.1	14.4	3.3
1 June	1600	14.4	-	-
2 June	1000	7.2	13.9	4.4
2 June	1045	7.8	-	-
2 June	1730	13.3	-	-
3 June	0945	6.7	-	5.0
3 June	1030	6.7	-	-
9 June	1815	12.2	-	-
10 June	0945	6.1	-	4.4
10 June	1120	7.8	-	-
10 June	1230	10.0	-	-
10 June	1900	12.2	13.3	-
11 June	0945	7.2	13.3	5.6
12 June	0900	6.7	-	6.1
12 June	1830	11.7	-	-
21 June	1800	13.3	-	-
22 June	1030	8.3	-	-

Appendix Table 12. Stream discharges in Beaver Creek, 1986.

Date	Time	Flow (m^3/s)
30 May	1600	2.251
31 May	1045	2.129
1 June	1800	2.603
2 June	1045	2.199
2 June	1745	2.447
3 June	1030	2.078
9 June	1815	2.389
10 June	1120	1.910
11 June	1745	1.889
12 June	1030	1.907
21 June	1800	0.997

Appendix Table 13. Tag returns from brown trout tagged in the Gardner River, Yellowstone National Park, on 31 October 1985 (data courtesy of Montana Department of Fish, Wildlife, and Parks).

Tag Number	Recapture Location	Date of Recapture	Recapture Method
3984	mouth of Gardner River	12/30/85	Angling
3951	Yellowstone River at Corwin Springs, MT	01/86	Angling
3913	Yellowstone River: 1.6 to 8 km downstream from Corwin Springs, MT	05/09/86	Electrofishing
4019		04/17/86	Electrofishing
4033		05/09/86	Electrofishing
4054		04/29/86	Electrofishing
4058		04/17/86	Electrofishing
4082		04/17/86	Electrofishing
4016	Yellowstone River: 6.4 km downstream from Mill Creek Bridge, MT	04/07/86	Electrofishing
4035	Yellowstone River: 8 km west of Springdale, MT	03/28/86	Electrofishing

Appendix Table 14. Tag returns from rainbow trout tagged in the Gardner River, Yellowstone National Park, on 3 and 25 March 1986 (data courtesy of Montana Department of Fish, Wildlife, and Parks).

Tag Number	Recapture Location	Date of Recapture	Recapture Method
4252	Yellowstone River: 3.2 km downstream from Mill Creek Bridge, MT	03/03/86	Electrofishing

APPENDIX B

Methods for Habitat Assessment

In each stream reach, three transects were established at the habitat inventory site. A 100 foot fiberglass tape was secured (with metal stakes) perpendicular to the direction of streamflow at the first transect. Streamflow was measured by the mid-section method (Buchanan and Somers 1969) at the first transect. Ten to fifteen velocity measurements were taken for each streamflow. Depth was also recorded at each velocity site. All of the depth measurements from the first transect were used to obtain average depth for that transect. At the second and third transect of each stream reach, depths were taken at approximately 0.25, 0.5, and 0.75 of the distance across the stream transect. These three depths were summed and divided by 4 to obtain an average depth for each transect (Platts et al. 1983).

The following habitat measurement techniques were used at each transect are reprinted directly from Platts et al. (1983).

Channel Width

The horizontal distance along the transect line from bank to bank (or high water mark to high water mark).

Stream Width

The horizontal distance along the transect line from shore to shore along the existing water surface. Width is that length of the transect line intercept over the stream channel and bank that is covered by water. Stream width is measured to the nearest 0.1 feet.

To provide consistency in measurement, protruding logs, boulders, stumps, or debris surrounded by water are included in the measurement of the water surface. Islands are not included in the measurement. Any solid accumulation of inorganic sediment particles protruding above the water and more than 1 foot width is considered an island. The stream width measurement ends when, on approaching the shoreline, any material is not completely surrounded by water and water is only pocketing between the material. These guidelines are necessary to obtain measurement consistency from year to year on the same stream.

Stream Shore Water Depth

The water depth at the stream shore is measured at the shoreline or at the edge of a bank overhanging the shoreline. If the angle formed by the bank as it meets the stream bottom is over 90°, the stream shore water depth reading is always zero. If the angle is 90° or less, the water column goes under the streambank and the measurement of the stream shore water depth is greater than zero. Measurements are taken to tenths of feet and the measurements for both shores are totaled and averaged to get the overall rating for the transect.

Riffle Width

Measure total width of riffle or riffles along transect line to the closest 0.1 feet.

Pools

Width: Measure total width of pool along transect line to closest 0.1 feet.

Quality: This rating (Appendix Table 1) requires that direct measurements of the greatest pool diameter and depth be combined with a cover analysis. Pool cover is any material or condition that provides protection to the fish from its predators or competitors, such as logs, organic debris, overhanging vegetation within 1 foot of the water surface, rubble, boulders, undercut banks, or water depth.

As the transect line crosses the water column surface, it can intercept one pool, many pools, pools and riffles, or riffles only. If more than one pool is intercepted by the transect line, then pool widths times their respective quality ratings are summed and this total divided by the total pool width to give the weighted average pool rating.

Feature: Designed to classify the condition that formed or is maintaining the pool (Appendix Table 2).

Appendix Table 1. Rating of pool quality, designed for streams between 20 and 60 feet in width.

1A	If the pool maximum diameter is within 10 percent of the average stream width of the study site	Go to 2A, 2B
1B	If the maximum pool diameter exceeds the average stream width of the study site by 10 percent or more	Go to 3A, 3B
1C	If the maximum pool diameter is less than the average stream width of the study site by 10 percent or more	Go to 4A, 4B, 4C
2A	If the pool is less than 2 feet in depth	Go to 5A, 5B
2B	If the pool is more than 2 feet in depth	Go to 3A, 3B
3A	If the pool is over 3 feet in depth or the pool is over 2 feet in depth and has abundant fish cover1)	Rate 5
3B	If the pool is less than 2 feet in depth, or if the pool is between 2 and 3 feet in depth and the pool lacks fish cover	Rate 4
4A	If the pool is over 2 feet with intermediate2) or bottom cover	Rate 3
4B	If the pool is less than 2 feet in depth but pool cover for fish is intermediate or better	Rate 2
4C	If the pool is less than 2 feet in depth and pool cover is classified as exposed3)	Rate 1
5A	If the pool has intermediate to abundant cover	Rate 3
5B	If the pool has exposed cover conditions	Rate 2

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1) If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.

2) Cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.

3) Cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

Appendix Table 2.

Feature forming the pool	Code
Log, tree, mot, stump, brush, or debris	1
Channel meander	2
Rubble or gravel	3
Boulder or bedrock	4
Stream channel	5
Fine sediment	6
Streambank	7
Culvert, bridge, or other man-made object	8
Beaver dam or tunnel	9

Streambank Soil Alteration

The streambank alteration rating reflects the changes taking place in the bank from any force (Appendix Table 3). The rating is separated into five classes. Each class, except the one with no alteration, has an evaluation spread of 25 percentage points. Once the class is determined, the observer must decide the actual percent of instability. Streambanks are evaluated on the basis of how far they have moved away from optimum conditons for the respective habitat type. Therefore, the observer must be able to visualize the streambank as it would appear under optimum conditions. Any natural or artificial alteration deviating from this optimum condition is included in the evaluation. This visualization makes uniformity in rating an alteration difficult, because it is difficult to train all observers to visualize the same optimum bank condition. Natural alteration is any change in the bank produced by natural events. Artificial alteration is any change obviously produced by exotic force. Trampling by man or livestock, disturbance by bulldozers, etc., are examples of artificial changes.

Streambank Vegetative Stability

This rating (Appendix Table 4) relates primarily to stability generated by vegetative cover, except in those cases where bedrock, boulder, or rubble stabilizes the streambanks. The rating takes all these protective coverings into account. The rated portion of the bank or flood plain includes only that area intercepted by the transect line within 5 feet of the stream to the top of the bank.

Appendix Table 3. Streambank soil alteration rating.

Rating	Description
Percent	
0	Streambanks are stable and are not being altered by water flows or animals.
1 to 25	Streambanks are stable, but are being lightly altered along the transect line. Less than 25 percent of the streambank is receiving any kind of stress and if stress is being received, it is very light. Less than 25 percent of the streambank is false, broken down, or eroding.
26 to 50	Streambanks are receiving only moderate alteration along the transect line. At least 50 percent of the streambank is in a natural stable condition. Less than 50 percent of the streambank is false, broken down, or eroding. False banks are rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
51 to 75	Streambanks have received major alteration along the transect line. Less than 50 percent of the streambank is in a stable condition. Over 50 percent of the streambank is false, broken down, or eroding. A false bank that may have gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
76 to 100	Streambanks along the transect line are severely altered. Less than 25 percent of the streambank is in a stable condition. Over 75 percent of the streambank is a false1) bank, that has gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.

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1) False banks are those banks which have been cut back by cattle and are no longer immediately adjacent to the stream. They can become stabilized by vegetation, but base flows are usually too far removed from the stream to provide fish cover.

Appendix Table 4. Streambank vegetative stability rating.

Rating	Description
4 (Excellent)	Over 80 percent of the streambank surfaces are covered by vegetation in vigorous condition or by boulders and rubble. If the streambank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3 (Good)	Fifty to 79 percent of the streambank surfaces are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2 (Fair)	Twenty-five to 49 percent of the streambank surfaces are covered by vegetation or by gravel or larger material. Those areas not covered by vegetation are covered by materials that give limited protection.
1 (Poor)	Less than 25 percent of the streambank surfaces are covered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

Streambank Undercut

The undercut, if it exists, is measured with a measuring rod directly under the transect line from the furthest point of protrusion of the bank to the furthest undercut of the bank; the water level does not influence this reading. The measurement is recorded to the nearest tenth of a foot. If more than one undercut occurs under the transect, only the dominant undercut is recorded.

Channel-Bank Angle

A clinometer is used to measure the angle formed by the downward sloping streambank as it meets the more horizontal stream bottom. If the streambank is undercut, the angle is always less than 90 degrees. The angle is determined directly from the clinometer placed on the top of the rod as it forms the angle determined by the protruding edge of the bank to the midpoint of the undercut under the transect line.

If the bank is not undercut, then the angle is 90 degrees or more and is read from the bank side by placing the clinometer on the top of the measuring rod that alined parallel to the streambank along the transect. The clinometer reading is subtracted from 180 degrees to get the bank angle.

A streambank angle over 90 degrees is easily read with precision and accuracy. An angle less than 90 degrees is more difficult to read as multiple undercuts can complicate the bank profile making it difficult to determine the points delineating the angle. The key is to include the midpoint of the dominant undercut in the bank profile.

Stream Channel Substrate

Surface visual analysis. The composition of the channel substrate is determined along the transect line from streamside to streamside. A measuring tape is stretched between the end points of each transect, and each 1-foot division of the measuring tape is projected by eye vertically to the stream bottom and the materials assigned to the major sediment class observed for each 1-foot division of the bottom. For example, 1 foot of stream bottom containing 4 inches of rubble, 6 inches of gravel, and 2 inches of fine sediment would be classified as 1 foot of gravel. With a large enough sample it is assumed that any bias in assigning the dominant sediment class would be compensated for. The individual 1 foot classifications are totaled to obtain the amount of bottom in each of the size classifications and these are totaled to equal the total transect width.

Embeddedness

Embeddedness rates the degree that the larger particles (boulder, rubble, or gravel) are surrounded or covered by fine sediments (Appendix Table 5). The rating is a measurement of how much of the surface area of the larger size particles is covered by fine sedient. This should allow evaluation of the channel substrate's suitability for spawing, egg incubation, and habitats for aquatic invertebrates, and young overwintering fish. The rearing quality of the instream cover provided by the substrate can be evaluated also. As the percent of embeddedness decreases, the biotic productivity is also thought to decrease.

Appendix Table 5. Embeddedness rating for channel materials (gravel, rubble, and boulder).

Rating	Rating Description
5	Gravel, rubble, and boulder particles have less than 5 percent of their surface covered by fine sediment.
4	Gravel, rubble, and boulder particles have between 5 and 25 percent of their surface covered by fine sediment.
3	Gravel, rubble, and boulder particles have between 25 and 50 percent of their surface covered by fine sediment.
2	Gravel, rubble, and boulder particles have between 50 and 75 percent of their surface covered by fine sediment.
1	Gravel, rubble, and boulder particles have over 75 percent of their surface covered by fine sediment.

Channel Vegetative Cover

Instream vegetative cover is measured directly along the transect line. Each 1 foot division of the measuring tape across the transect is evaluated. If more than 50 percent of the foot contains cover, the complete foot is classified as cover. If not, it is ignored. Cover includes algal mats, mosses, rooted aquatic plants, organic debris, downed timber, and brush capable of providing protection for young-of-the-year fish. Thin films of algae on the channel substrate would not be included.

Streamside Cover

This rating considers all material (organic and inorganic) on or above the streambank that offers streambank protection from erosion and stream shading, and provides escape cover or resting security for fish (Appendix Table 6). It inclues only that cover intercepted by the transect line.

Appendix Table 6.

Rating	Description
4	The dominant vegetation is shrub.
3	The dominant vegetation influencing the streamside and/or water environment is of tree form.
2	The dominant vegetation is grass or forbs.
1	Over 50 percent of the streambank transect line intercept has no vegetation and the dominant material is soil, rock, bridge materials, road materials, culverts, or mine tailings.

Vegetation Use

Vegetation use under the transect line within 5 feet of the shoreline is rated visually. This evaluation considers vegetation disturbed during the present growning season and potential plant growth that does not exist because of past disturbance. An example of loss because of past use would be in areas where vegetation no longer exists because the streambank was dredged, trampled, or eliminated by an animal crossing. The rating, however, applies mainly to recent vegetation use. If use is determined on only one occasion or only one time a year, it should be done as soon as possible after the land use effect and before plant regrowth can occur.

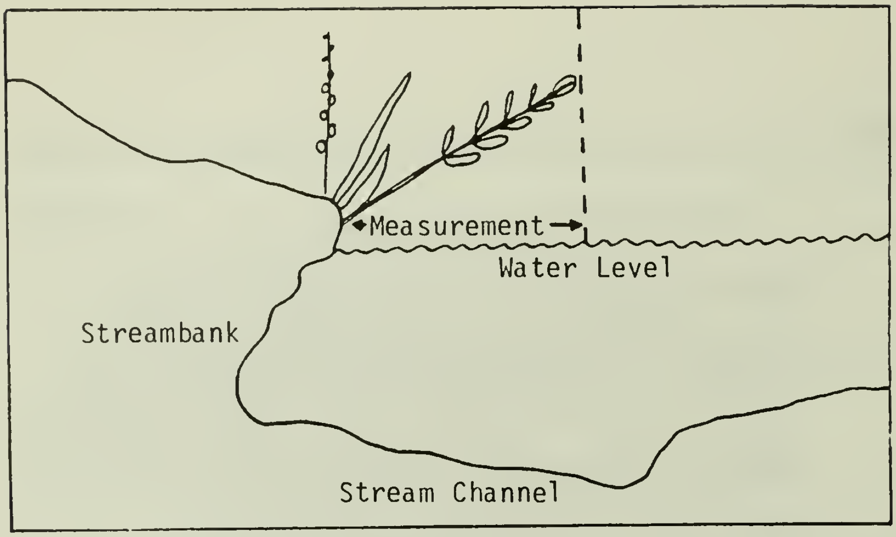
The vegetation use rating is stratified into four classes (Appendix Table 7). Once the observer has decided the class, then the actual percentage use is determined. For example, if the vegetation (grasses and forbs) has been reduced to less than 2 inches (50.8 mm) stubble standing height, the class rating is between 76 and 100 percent. If the vegetation is almost to ground level, the final intraclass rating would be 100 percent. If the vegetation is slightly less than 2 inches (50.8 mm) stubble height and there are no areas without vegetation from past use, then the intraclass rating would be about 76 percent.

Appendix Table 7.

Rating (percent)	Description
0 to 25 (Light)	Vegetation use is very light or none at all. Almost all the potential plant biomass at present stage of development remains. The vegetative cover is very close to that which would occur naturally without use. If bare areas exist, (i.e., bedrock) they are not because of loss of vegetation from past grazing use.
26 to 50 (Moderate)	Vegetative use is mderate and at least one-half of the potential plant biomass remains. Average plant stubble height is greater than half of its potential height at its present stage of development. Plant biomass no longer on site because of past grazing is considered as vegetation that has been used.
51 to 75 (High)	Vegetative use is high and less than half of the potential plant biomass remains. Plant stubble height averages over 2 inches. Plant biomass no longer on site because of past grazing is considered as vegetation that has been used.
76 to 100 (Very High)	Use of streamside vegetation is very high. Vegetation has been removed to 2 inches or less in average stubble height. Almost all of the potential vegetative biomass has been used. Only the root system and part of the stem remain. That potential plant biomass that is now nonexistent because of past elimination by grazing is considered as vegetation that has been used.

Vegetation Overhang

Vegetation overhang indirectly provides fish food and cover and shades the water from solar radiation. Streamside cover rates all vegetation. Vegetation overhang rates only that vegetation overhanging the water column (Appendix Figure 1).



Appendix Figure 1. Measurement of overhanging vegetation.

This is a direct measurement to the nearest 0.1 foot of the vegetation (excluding tree trunks or downed logs) within 12 inches of the water surface and overhanging the water column.

The measurement is taken along the transect line, beginning at the farthest protrusion of the streambank over the water column. This measurement does not include the undercut; therfore, the two measurements combined, give the total overhead cover.

Habitat Type

The streamside environment consists of many types of habitats and it is often theorized that the type and diversity can determine fish productivity. The habitat type evaluates only the channel-streambank area intercepted by the transect within 10 feet of the stream shore. This rating is an evaluation of the dominant and subdominant material (organic or inorganic) composing the surface or overstory of the streamside environment. Combinations of plant and soil usually make up this environment, but occasionally a single material, such as sand or log, will describe the habitat type.

This rating was designed with the assumption that streamside environments composed of fine sediments (sand) have less value to fish than brush-sod environements, which have the highest values. All other habitat types fall between these two extremes (Appendix Table 8). All existing cover is considered, but only the dominant and subdominant materials are selected for the final classification. The subdominant type would be the second most abundant material.

Appendix Table 8. Streamside habitat type rating.

Rating	Streambank Material	
	Dominant	Subdominant
1	All Fines1)	
2	Fines	Gravel
2	Fines	Grass
2	Fines	Rubble
3	Fines	Boulder
3	Fines	Root2)
3	Fines	Tree3)
3	Fines	Sod4)
3	Fines	Brush
4	Gravel	Fines
5	All Gravel	
6	Gravel	Grass
6	Gravel	Rubble
7	Gravel	Boulder
8	Gravel	Root
8	Gravel	Tree
7	Gravel	Sod
8	Gravel	Brush
8	Grass	Fines
9	Grass	Gravel
9	All Grass	
9	Grass	Rubble
9	Grass	Boulder
11	Grass	Root
12	Grass	Tree
13	Grass	Sod
17	Grass	Brush
8	Rubble	Fines
9	Rubble	Gravel
9	Rubble	Grass
10	All Rubble	
10	Rubble	Boulder
11	Rubble	Root
11	Rubble	Tree
11	Rubble	Sod
12	Rubble	Brush
11	Boulder	Fines
12	Boulder	Gravel
12	Boulder	Grass
12	Boulder	Rubble
12	All Boulder	
13	Boulder	Root
13	Boulder	Tree
13	Boulder	Sod
13	Boulder	Brush

Appendix Table 8. continued.

	Streambank Material	
Rating	Dominant	Subdominant
12	Root	Fines
13	Root	Gravel
12	Root	Grass
13	Root	Rubble
13	Root	Boulder
13	All Root	
14	Root	Tree
13	Root	Sod
14	Root	Brush
12	Tree	Fines
13	Tree	Gravel
13	Tree	Grass
13	Tree	Rubble
13	Tree	Boulder
14	Tree	Root
14	All Tree	
14	Tree	Sod
14	Tree	Brush
12	Sod	Fines
13	Sod	Gravel
14	Sod	Grass
15	Sod	Rubble
16	Sod	Boulder
18	Sod	Root
18	Sod	Tree
17	All Sod	
19	Sod	Brush
17	Brush	Fines
20	Brush	Gravel
20	Brush	Grass
21	Brush	Rubble
22	Brush	Boulder
23	Brush	Root
23	Brush	Tree
24	Brush	Sod
23	All Brush	

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1) Fines include sands, silts, clays, and organic fine particle materials.
2) Includes only roots from brush and trees.
3) Downfall logs included.
4) Sod has an extensive root mass and is more stable than grass or grass tufts.

Modifications for Reese Creek

Solar angle was determined by means of a clinometer. Two readings were taken from mid-channel at each transect. The angle to the highest sunlight obstruction (vegetation or hill) in both an easterly and westerly direction was recorded. These two angles were summed and subtracted from 180° to yield the solar angle for that particular transect.

Distance between transects was measured as 10 times the stream width of the previous transect. This distance was measured along the streambank with the tape and paralleled the thalweg. Stream gradient and sinuosity were determined from the mid-channel point of two adjacent transects. Sinuosity was obtained by stretching the tape straight between the two mid-channel transect points. The ratio of streambank length divided by straight line distance was recorded as sinuosity (always greater than 1). Gradient was measured with a clinometer by reading the angle between the same two points used for sinuosity. Two poles of equal length were used to assure accuracy in gradient readings.